PESTICIDE APPLICATION METHODS FOR CITRUS IN FLORIDA

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Abstract. Since the introduction of the first dilute airblast sprayer to Florida citrus in 1937, the trend has been toward lower liquid volume applications because of improved insecticides and sprayers, successful biological control, and the increased marketing of processed fruit. Ninety-five percent of the pesticides are applied by tractor drawn airblast sprayers at ground speeds of 1.5 to 3 kph. High air volume airblast sprayers discharge 14 to 47 m³/s of air at spray application rates of 1000 to 14000 liters per acre and spray up to 14 m/s and 1000 l/ha, respectively.

For the past 2 decades, aerial spraying has been accomplished with helicopters and fixed wing aircraft at spray application rates of 50 to 150 l/ha. Helicopters are generally better suited for rolling terrain and shorter rows of the interior groves while fixed wing aircraft are best employed on the longer rows of the bedded citrus along the east coast of Florida.

Pest control programs used by Florida citrus growers have changed over the past 2 decades and have resulted in some changes in pesticide application methods. Successful biological control of a number of armored scales had shifted attention to an emphasis on chemical control of citrus rust mite, Phylococcus oleivora Ashm. and greasy spot disease, Myscotheca citri Whitehouse. Annually, control of citrus rust mite requires 1 to 3 acaricide applications and greasy spot disease requires 1 to 2 fungicide applications. The degree of control of these 2 pests is determined by their effects on (a) the juice yield and health of the tree and (b) the cosmetic appearance of fresh market fruit. Because of the trend toward greater utilization of Florida citrus for processing, presently 87% of total crop (15), the influence of factor (a) in pesticide application decisions has increased. Also, decreasing profit margins in the last decade have caused many growers to use lower cost pest control programs.

Generally citrus snow scale, Uraspis citri (Comst.), infestations increased after 1960 and only dilute applications were found to provide some degree of control (7). This requirement for high volume spraying slowed the development of concentrated low volume methodology. However, the introduction of a number of lymoenopterous parasites of the genus Aphytis has given biological control of the important armor scales and reduced the need for routine scallop applications at dilute rates (12). Control of greasy spot disease requires good coverage (29), but not necessarily dilute applications, although many growers use dilute rates to achieve good coverage.

It is the purpose of this paper to discuss the development of the more common applications methodology presently used in Florida citrus. Research results to date, and trends of the future.

Development of Pesticide Application Methodology

Airblast Sprayers

Although pesticides are applied with both airblast (ground) and aircraft sprayers, it is estimated that 95% of the treatments are applied by ground units.

The airblast sprayer is basically an air carrier type of sprayer which is usually tractor-drawn and uses air from a fan to carry pesticide droplets to impinge on a target. Airblast sprayers have been classified in 2 basic categories—high air volume (generally greater than 14 m³/s (30000 cfm)) with high liquid delivery and low air volume with low liquid delivery.

High air volume. There has been a continuing effort to evaluate and improve pesticide application equipment since the first high air volume, airblast sprayer was introduced in Florida citrus in 1937. This first unit was a dilute sprayer and being a successor to the handgun, it applied 80 to 120 l (20 to 30 gal) per mature tree at 1.5 to 3 kph (1 to 2 mph) ground speed. It was powered by an auxiliary engine and delivered 19 to 24 m³/s (40000 to 50000 cfm) of air at 140 to 160 kph (90 to 100 mph) with a vane axial fan. Although this method reduced the amount of labor needed to spray citrus trees, it nevertheless required very large quantities of water. Investigations (16, 17, 26) began to reduce the volume of water or to use more concentrated sprays. Compared to dilute, gallonage was reduced to 1/8 although the chemical was concentrated 6 times. This resulted in a 20% savings in the amount of chemical needed for effective control. Whitney (30) has discussed how reduced gallonage and lost time as well as increased ground speed can lower application costs.

King et al. (18) reported that attachments (a stack) which increased the height of air discharge and controlled air movement improved the performance of the large air blast sprayer. Brooks (4) found that another type of stack did not improve performance. Brooks et al. (5) reported some improvement in performance by increasing pump pressure of the spray delivery system to 14 kg/cm² (200 psi) and by using oscillating vanes in the air discharge for dilute applications. However, oscillating vanes in the air discharge did not improve coverage for low volume applications at 1/8 the dilute gallonage.

Typical high air volume, airblast sprayers which are presently in use are shown in Figs. 1 and 2. Power is provided by a 60 to 112 kw (80 to 150 hp) auxiliary engine or a tractor power take off (pto) of 37 to 63 kw (50 to 85 hp). Because of the trend toward increasing tractor horsepower, more sprayers are being designed and offered as pto-powered.

The air handling system consists of an axial flow fan whose air is turned 90° and discharged radially to both
Fig. 2. Mesa Model 142 sprayer powered by tractor tractor. The tanks have a capacity ranging from 110 to 1,000 gal (420 to 4,000 l) and deliver up to 60 gpm (230 l/min). The sprayer can be driven by a tractor, industrial engine, or electric motor. The sprayer can deliver a liquid spray or a high pressure spray. The liquid spray is used for tillage operations, while the high pressure spray is used for spraying crops. The sprayer is equipped with a hydraulic system to control the flow of liquid and the pressure of the spray. The hydraulic system is powered by a hydraulic pump, which is driven by a tractor tractor engine. The hydraulic pump delivers the liquid to the nozzles, which are mounted on the boom of the sprayer. The nozzles are adjustable and can be set at different angles and pressures to achieve the desired spray pattern. The sprayer is also equipped with a ground control system, which allows the operator to control the flow of liquid and the pressure of the spray from the ground. This system is used to adjust the spray pattern and the pressure of the spray to achieve the desired results. The sprayer is also equipped with a boom control system, which allows the operator to control the movement of the boom. This system is used to adjust the position of the boom to achieve the desired spray pattern. The sprayer is also equipped with a safety system, which prevents the operator from damaging the equipment. This system is used to prevent the operator from damaging the equipment and the environment.
(150 to 200 mph) which are essential for spray droplet formation at the discharge. From the fan, the air is turned 90° and discharged to both sides of the sprayer. Fan wheel sizes range up to 0.56 m (22 inches) and deliver up to 7 m³/s (15000 cfm). The air discharges have some provisions for adjustment of the air pattern for tree height. Several manufacturers have recently introduced low air volume sprayers with stacks to achieve better coverage in tree tops.

The liquid handling system utilizes a 750 to 1150 l (200 to 300 gal) tank which is usually fiber glass. A centrifugal pump circulates the spray liquid at 4 to 8 l/s (60 to 120 gpm) and 1.4 to 2 kg/cm² (20 to 30 psi). Less than 0.7 l/s (10 gpm) is delivered through adjustable orifices or valves to the nozzles while the remainder is returned to the tank for hydraulic agitation. Care must be exercised with this agitation system to prevent nutritional materials from settling out in the tank. Strainers in the liquid handling system prevent stoppages and damage. Although nozzles are of various designs, most of them simply discharge the liquid at near atmospheric pressure into the high velocity air discharge. The high velocity air serves the dual purposes of breaking up the spray liquid into droplets and carrying them to the target. A reasonably uniform droplet size distribution is achieved by keeping the application rates below 950 l/ha (100 gpa). Application rates normally range from 280 to 470 l/ha (80 to 50 gpa) at ground speeds of 1.6 to 3.2 kph (1 to 2 mph). Field capacities normally range from 0.8 to 2 ha/hr (2 to 5 acre/hr) with one sprayer required to care for 200 ha (500 acres). A ground spraying system is similar to that of the high air volume sprayer except that one or no supply trucks are required, depending on the application rate and availability of water.

The low air volume sprayer has gained acceptance in the past decade because it is simpler and less costly to operate than the high air volume sprayer. It has shown merit in the bedded citrus areas of Florida because (a) its size and lightweight features making maneuvering easier in the ditches and (b) generally smaller trees in this area favor the use of a smaller sprayer.

**Aircraft Sprayers**

Aerial application of pesticides is accomplished with helicopters and fixed wing airplanes. It is estimated that 3 to 4% of the citrus acreage is under a complete aerial program while about 10% of the citrus acreage receives at least one aerial application annually as a supplement to ground spraying.

**Helicopters.** Aerial applications in Florida citrus have been in use for at least 2 decades with few changes in equipment (2, 5, 18). Until recently, most helicopters applied their sprays through 30 to 50 nozzles on a boom. Liquid was furnished by a centrifugal pump at about 2.8 kg/cm² (40 psi). Brooks (4) reported that the helicopter achieved optimum coverage flying down the row middles at about 40 kph (25 mph). Application rates were 93 l/ha (10 gpa).

Figure 4 shows a typical helicopter sprayer which is presently in use. Some of the helicopters have recently changed from pressure nozzles to rotary atomizers (Fig. 5). Only 4 or 5 of these atomizers are required. Application rates vary from 28 to 140 l/ha (3 to 15 gpa). Ground speeds of helicopters are 32 to 56 kph (20 to 35 mph). Their field capacity is 8 to 1.4 ha/hr (20 to 35 acre/hr) with a tank size of 280 l (75 gal) on a small helicopter such as the Bell 47-2GA and 900 l (240 gal) on a large helicopter such as the Sikorsky H-19. Pesticides are applied mainly in the early daylight hours when wind conditions are calm. One helicopter can normally cover 600 to 1000 ha (1600 to 2500 acres) where citrus is on a complete aerial program. A helicopter spray system normally consists of a helicopter with pilot, and a supply truck and trailer with 2 men.

**Fig. 5. Beecomist Spray Head (rotary atomizer) as mounted on helicopter sprayer.**

Helicopters are mainly used in the interior citrus region of Florida where the terrain is rolling and many groves have row lengths of approx 400 m (1/4 mile). They spray small acreages on complete aerial programs and play an important role in making supplemental applications to citrus generally sprayed by ground sprayers.
Fixed wing aircraft. Aerial applications of pesticides by fixed wing aircraft have been made for over a decade (8). They have been utilized mainly on the bedded citrus groves of east and south Florida. Thirty to forty pressure nozzles at 2.8 kg/cm² (40 psi) on a boom attached all of the trailing edge of the wing were first used to distribute the spray at rates up to 93 l/ha (10 gpa) (8, 9). Ground speeds were 140 kph (90 mph) and passes are made over the row middles.

More recent applications (10, 13) have employed rotary atomizers for distribution of the spray (Fig. 6). The commonly used aircraft are the Cessna ‘Ag Truck,’ the Rockwell American ‘Thrush,’ and the Snow ‘Ag Tractor.’ Pilots fly progressive swaths at tree-top height between tree rows (middles) at about 160 kph (100 mph). Fungicides and nutritionalts are applied at 140 l/ha (15 gpa) and miticides at 93 l/ha (10 gpa) through micronair AU 3000 rotary atomizers or booms fitted with Spraying Systems D10-45 nozzles. Beemeston Spray Heads are used for application less than 10 l/ha (1 gpa). Dusts are applied in every other middle. As with helicopters, fixed wing aircraft make their applications mainly under calm conditions. The field capacity of a fixed wing aircraft is 20 to 32 ha/hr (50 to 80 acre/hr) and it can normally cover 1600 to 2800 ha (4000 to 7000 acres) of citrus on a complete aerial program. A fixed wing aircraft spray system normally includes an airplane and pilot and a supply truck with driver.

![Fig. 6. Micronair AU 3000 (rotary atomizer) as mounted on trailing edge of wing of fixed wing aircraft.](image)

Fixed wing aircraft play a significant role in pesticide applications in citrus along the east coast of Florida. At least half the citrus in this area received 1 aerial application in 1977. The citrus in this area is characterized by long rows, small trees, and drainage ditches which makes terrain difficult to operate airblast sprayers.

Field Results

Since the introduction of the high air volume airblast sprayer with high liquid (dilute) delivery in 1937, satisfactory applications at lower liquid levels have been sought. Griffiths et al. (16), Stearns et al. (26), and Thompson et al. (28) all reported that concentrating the spray 6 times and using 1/8 as many gallons were equivalent to a dilute application.

King et al. (18) first reported on results with helicopter compared with airblast sprayers. They found that copper deposition with helicopter compared favorably with ground sprayers on leaf tops, but not on leaf bottoms. Brooks et al. (5) and Brooks (2) found that helicopter applications of chlorobenzilate satisfactorily controlled citrus rust mite, but that scaricide applications were not effective against Glover scale. In the same tests, high air volume airblast sprayers at dilute and concentrate rates did control rust mite and scaricide applications were significantly more effective than those of the helicopter. Low air volume or concentrate ground sprayers were effective against rust mite at all concentrations, but only effective down to 1/10 the dilute gallonage against Glover scale. Other tests by Brooks (4) showed that some low air volume or concentrate sprayers at 1/20 the dilute gallonage provided comparable control of armored scale insects as the high air volume sprayer at dilute rates.

Citrus scale was difficult to control with scaricides, especially for concentrate applications. Brooks and Whitney (7) compared ground sprayer with helicopter applications and found that only dilute and 1/2 the dilute gallonages significantly reduced scale populations.

In 1971, Brooks and Whitney (6) reported on a 2-year field trial in Pineapple oranges with various airblast sprayers. The overall superiority of the high air volume sprayer was demonstrated by insect counts and checking fruit blemishes at harvest time. Both high air volume sprayers at 1/8 dilute gallonage and low air volume sprayers at 1/20 dilute gallonage were evaluated.

Applications with fixed wing aircraft were reported to be effective against aphids, black scale, and citrus rust mite in the east coast counties of Florida (9, 10, 11). Other tests in the same area by Bullock et al. (13) showed that helicopter, fixed wing aircraft, and various airblast sprayers provided similar control of rust mite, melano and greasy spot when using fruit blemishes at harvest time as an indicator.

The same investigation also revealed that acceptable levels of manganese and zinc were maintained in trees by aerial application of nutritionalts. Aerial applications, however, were not as effective as airblast sprayers in controlling greasy spot lesions on leaves. Other tests in 1976 illustrated that although the grapefruit trees at the test site were severely infected with greasy spot disease, there was no significant difference in control with either airblast or helicopter sprayer.

The discovery that aerial application of oil by Schroeder et al. (24) interfered with successful attachment of egg clusters deposited by the sugarcane rootstalk borer weevil, Diastrocus abbreviatus, on citrus foliage has provided an additional tool in the effort to eradicate this exotic pest from Florida. The addition of the IGR dicyflumuron to the 1:1 oil-water emulsion spray reduced egg viability by 95% for a month after application (22).

Future Trends

Soil applications of systemic insecticides have potential for future insect control. The efficacy of soil treatments with systemic insecticides for citrus insect and mite control has been documented by a number of investigators (1, 3, 14, 19, 20, 21, 24, 25, 27), but methods have not been mechanized for commercial application.

For the past 2 years granular aldicarb has been distributed by shank and broadcast methods in a Valencia orange grove near Fort Pierce. With the shank method, the granules were placed beneath the soil surface behind 6 shanks, 0.35 m (14 inches) apart. The broadcast method distributed the granules uniformly over a 1.75 m (70 inches) width. The application swath extended outward from the tree canopy on both sides (row middles) of the tree.

Tables 1 and 2 show the results of these trials. The
shanked method provided the most consistent control of whitefly whereas mites were controlled successfully regardless of rate or method of application.

Table 1. 1976 granular Temik soil treatment—Gates Grove, Ft. Pierce, FL.

<table>
<thead>
<tr>
<th>Lb A1 per acre</th>
<th>Application method</th>
<th>Average per leaf</th>
<th>% Infested with rust mite</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>White fly</td>
<td>Spider mites</td>
</tr>
<tr>
<td>5</td>
<td>band</td>
<td>4.8a</td>
<td>2</td>
</tr>
<tr>
<td>10</td>
<td>band</td>
<td>0.8a</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>shanked</td>
<td>2.6a</td>
<td>1</td>
</tr>
<tr>
<td>10</td>
<td>shanked</td>
<td>0.8a</td>
<td>2</td>
</tr>
<tr>
<td>0</td>
<td>—</td>
<td>14.4b</td>
<td>5.6</td>
</tr>
</tbody>
</table>

*Temik 15G applied 30 Mar 76.*

*Means separation within columns by Duncan’s multiple range test.

Table 2. 1977 granular Temik soil treatment—Gates Grove, Ft. Pierce, FL.

<table>
<thead>
<tr>
<th>Lb A1 per acre</th>
<th>Application method</th>
<th>Average per leaf</th>
<th>% Infested with rust mite</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>White fly</td>
<td>Texas mites</td>
</tr>
<tr>
<td>5</td>
<td>band</td>
<td>1.3ab</td>
<td>5.2b</td>
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<tr>
<td>10</td>
<td>band</td>
<td>1.2ab</td>
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<td>1.5a</td>
</tr>
<tr>
<td>3.3</td>
<td>shanked</td>
<td>0.7a</td>
<td>1.3a</td>
</tr>
<tr>
<td>6.6</td>
<td>shanked</td>
<td>1.8b</td>
<td>9.7c</td>
</tr>
</tbody>
</table>

*Temik 15G applied 30 Mar 77.*

*Survey conducted 8 weeks posttreatment.

More concentrated or low volume types of application for pest control are expected in the future because of the trend toward marketing processed fruit, tree size and shape control, the introduction of improved selective insecticides, the introduction of additional biological control agents, and the development of better sprayers. Pto-driven airblast sprayers will become more common because of the trend toward increasing tractor horsepower. Greater operator protection will be demanded in the way of controlled-environment cabs, pre-packaged chemicals, and closed chemical handling systems. Aerial application will continue to become more commonplace because of their ability to make timely applications.

**Literature Cited**


