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PESTICIDE APPLICATION METHODS FOR CITRUS IN FLORIDA[1]

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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 m^3/s of air at spray application rates of 1000 to 14000 liters per hectare (l/ha). Low air volume airblast sprayers discharge air and spray up to 14 m^3/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, *Phyllocoptruta oleivora* Ashm. and greasy spot disease, *Mycosphaerella citri* Whiteside. Annually, control of citrus rust mite requires 1 to 3 acaracide applications and greasy spot disease requires 1 to 2 fungicide applications. The degree of control of these 2 latter 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, *Unaspis 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 hymenopterous parasites of the genus *Aphytis*[2] has given biological control of the important armor scales and reduced the need for routine scalicide 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 m^3/s (30000 cfm)) with high liquid delivery and how 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 to 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 m^3/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 25% 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/cm^2 (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

[1]Florida Agricultural Experiments Stations Journal Series No. 1318.
[2]*Aphytis lepidosaphes* Compere, *A. holoxanthus* Debach, and *Aphytis lingnanensis* (HK-1) Compere.
[3]Mention of commercial organizations or products in this report is solely to provide specific information. It does not constitute endorsement by the University of Florida over other organizations or products not mentioned.

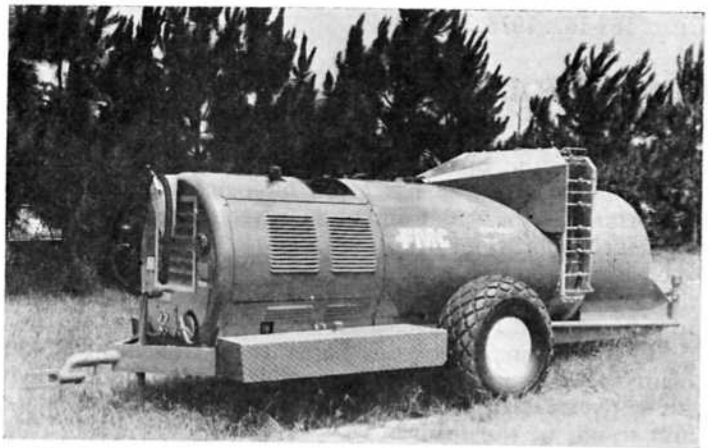

Fig. 1. FMC Model 757 CP sprayer with double oscillating citrus volute and powered by auxiliary engine.

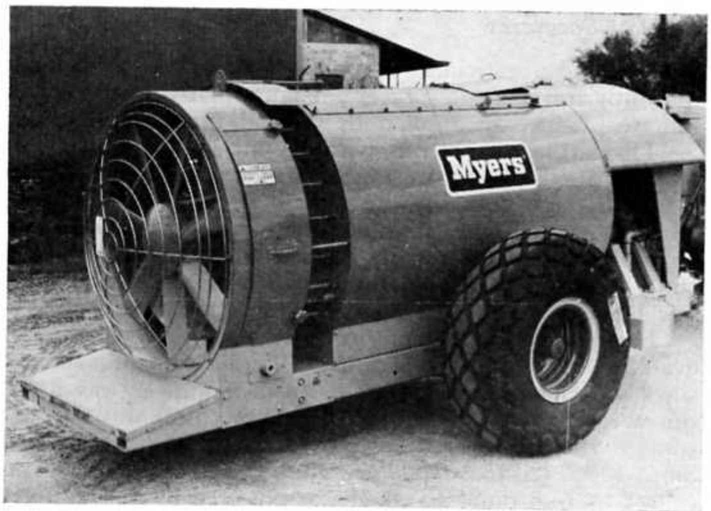

Fig. 2. Myers Model A42 sprayer powered by tractor pto.

sides of the sprayer. Fan diameters range from 0.74 to 1.11 m (29 to 44 inches) and deliver from 14 to 47 m^3/s (30000 to 100000 cfm) of air at discharge velocities of less than 175 kph (110 mph). Some sprayers utilize adjustable and oscillating deflectors in the air discharge to adjust the air delivery to different tree characteristics. One manufacturer has recently introduced a pto-powered sprayer with a stack in an attempt to achieve better coverage in tree tops at low volume application rates.

In the liquid handling system, the tank size normally ranges from 1100 to 1900 *l* (300 to 500 gal). Some of the sprayers have been modified to accept 3780 *l* (1000 gal) tanks for high gallonage applications and one manufacturer has recently introduced a (1000 gal) sprayer. Mechanical agitation is usually provided to insure suspension of various nutritional materials (zinc, manganese, boron, etc.) used extensively on Florida citrus. Materials for tank construction have been coated steel, stainless steel, and fiberglass with a definite trend toward the latter 2 materials because of their superior resistance to corrosion.

Spray liquid is supplied to the nozzles by either a centrifugal or piston pump. Centrifugal pumps deliver up to 6 liters per second (*l*/s) (100 gpm) at 7 to 14 kg/cm^2 (100 to 200 psi) and are designed for higher gallonage applications. Piston pumps deliver up to 2 *l*/s (35 gpm) at 28 kg/cm^2 (400 psi) and are designed for lower gallonage applications on pto-powered sprayers. Abrasive powders normally used in the pest control program cause considerable wear in pumps, especially in the piston type. Strainers are provided to prevent damage and stoppages of the pump and nozzles. Nozzles in the air discharge consist of whirlplates and discs with orifices for droplet formation and metering purposes. These internal components to the nozzle are usually made of stainless steel, tungsten, or ceramic. Application rates vary from a low of 930 *l*/ha (100 gpa) for the pto-powered sprayers to a high of 14000 *l*/ha (1500 gpa) for the largest sprayers. Field capacities range from 0.8 to 1.6 ha/hr (2 to 4 acres per hour (A/hr)) at ground speeds of 1.6 to 3.2 kph (1 to 2 mph). One sprayer is normally needed to care for 200 ha (500 A). A ground spraying system consists of a sprayer, tractor, and driver with 1 or 2 supply trucks with drivers. The number of supply trucks depends on the application rate and the availability of water. A truck to haul the tractor and tow the sprayer is usually necessary if intergrove travel distance is great.

The high air volume, airblast sprayer continues to be used in Florida citrus for the following reasons. The mature citrus tree is often maintained at a height of 20 ft or more and is usually thickly foliated, making spray coverage difficult. Much of the citrus is sprayed by cooperatives and caretakers who spray large acreages under widely varying grove, pest, and wind conditions. These operating conditions make good use of the versatility of the high air volume sprayer and help to justify its higher operating cost compared to low air volume sprayers.

Low air volume. Although the Florida citrus industry had been interested in concentrate (low volume) spraying since the early 1950's, sprayers designed specifically for this purpose were not introduced in significant numbers until the early 1960's. These concentrate sprayers were generally designed to apply less than 930 *l*/ha (100 gpa) and were illustrated by Brooks (4). One used a metering pump to deliver the spray material to 6 pneumatic nozzles operated at about 2.5 kg/cm^2 (35 psi). The sprayer was pto-driven with 34 kw (45 hp) and was one-sided with an air volume flow rate of 10 m^3/s (20000 cfm) at 112 kph (70 mph) from a vane axial fan. A second sprayer was also pto-driven with 37 kw (50 hp), was one-sided, and used a high pressure pump 28 kg/cm^2 (400 psi) to deliver spray liquid to 4 individual round air outlets. A centrifugal fan generated about 5 m^3/s (10000 cfm) at 240 kph (150 mph). The third sprayer (experimental) was engine driven with 60 kw (80 hp) and used a ground-wheel-driven metering pump to deliver the spray mixture at low pressure of 1.4 kg/cm^2 (20 psi) to 10 rotary nozzles. Air movement in the air discharges rotated the nozzles. The sprayer was double-sided and had 2 vane axial fans which delivered about 14 m^3/s (30000 cfm) of air at 208 kph (130 mph). All of these concentrate sprayers gained limited acceptance for several reasons. They were complex and had mechanical problems. They were introduced in the 1960's when snow scale infestations were on the increase and concentrate spraying had demonstrated little effectiveness to control this insect.

Within the past decade, another type of concentrate sprayer was introduced in Florida citrus. It was pto-powered with 30 to 45 kw (40 to 60 hp) and had a centrifugal fan that delivered a total of 5 m^3/s (10000 cfm) of air (double-sided) at 290 kph (180 mph). It utilized a low-pressure of 1.4 kg/cm^2 (20 psi) liquid delivery system to supply spray liquid to simple, low pressure nozzles in the air discharge. The high-velocity air discharge sheared the spray liquid from the nozzle to form spray droplets.

A typical low air volume sprayer which is presently in use is shown in Fig. 3. These units are normally powered by the tractor pto of up to 52 kw (70 hp), but are also offered with auxiliary power up to 67 kw (90 hp).

The air handling system uses a centrifugal fan because of its ability to generate the high velocities 240 to 320 kph

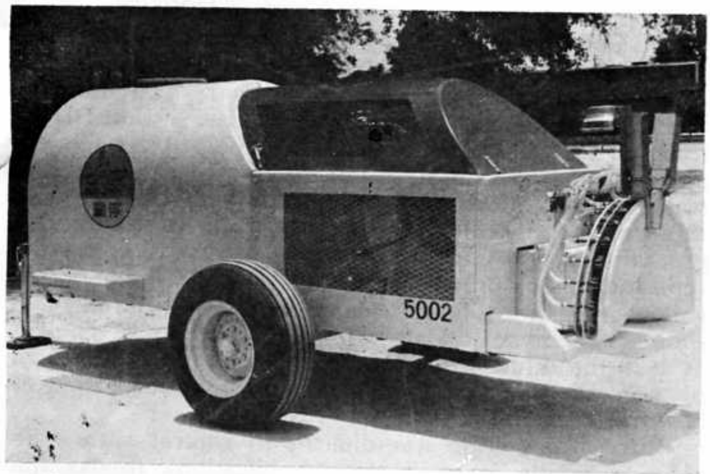

Fig. 3. Ag Tec Model 5002 sprayer powered by tractor pto.

(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 m^3/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/cm^2 (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 930 *l*/ha (100 gpa). Application rates normally range from 280 to 470 *l*/ha (30 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/cm^2 (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[3] 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. 4. Bell Model 47-2GA helicopter with 4 Beecomist Spray Heads.

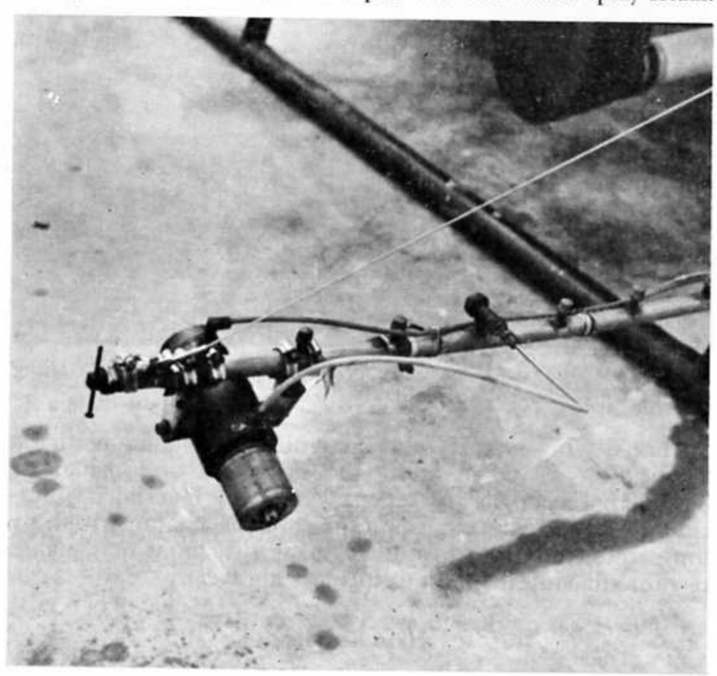

Fig. 5. Beecomist Spray Head (rotary atomizer) as mounted on helicopter sprayer.

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.