ABE-356

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2011 Florida Citrus Pest Management Guide: Pesticide Application Technology[1]

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SPRAYING TREES

Sprayer Selection

Most Florida citrus applications are made with air-carrier ground sprayers. These sprayers may be truck/tractor-mounted, tractor-drawn (p.t.o./ engine-driven), or self-propelled. They may be equipped with a positive or non-positive displacement pump to pressurize the spray liquid and generate spray droplets by hydraulic nozzles, air-shear nozzles, or rotary atomizers. Spray droplets are normally transported by sprayer airflow, generated with one or more axial-, centrifugal-, or cross-flow fans. The air is directed toward the canopy by a series of fixed, adjustable, or moving deflectors (oscillators). Some sprayers use a short or tall tower attachment to discharge a portion of the spray-laden air close to the upper parts of the tree canopy. Sprayers may use mechanical and/or hydraulic agitation systems.

The differences in size, shape, design features, and construction material of the sprayers could result in substantial variation in the price of the spray equipment. Nevertheless, a higher price does not necessarily mean a better sprayer or guarantee more satisfactory spray coverage. A pesticide can be expected to be effective if the 'right material' is applied, at the 'right amount', on the 'right target', at the 'right time', with the 'right sprayer', under the 'right weather' conditions. A cheap sprayer, adjusted and operated properly, may result in better pest control than a sophisticated sprayer used improperly under adverse weather conditions.

Sprayer Air Capacity

Since air-blast applications depend on the sprayer air stream to deposit the spray on the tree, the air volume and velocity must be sufficient for efficient droplet transport, acceptable penetration inside the canopy, and satisfactory spray coverage. However, air-carrier sprayers have a wide range in air capacities (5,000-100,000 cfm). While larger

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sprayers generate much more air volume than the smaller ones, they may not provide any improvement in spray coverage, and in some cases, too much air may adversely affect spray deposition by increasing spray runoff from leaf surface.

As the fan power requirement changes with the cubic factor of the airflow rate (fan speed) excessive air capacities dramatically increase the needed horsepower for fan operation. A 10-20% increase in fan speed increases the fan power demand by 33.1-72.3%, respectively. On the other hand, a 10-20% decrease of the speed reduces the power requirement by 27.1-48.8%, respectively. Higher energy demand of the fan requires purchasing a larger sprayer or operating the fan at higher rotational speeds. These practices would increase capital investment, fuel consumption, and operating costs. Therefore, smaller fans or lower rotational speeds should be used as much as possible. Using lower air volumes could offer substantial savings in energy expenditure and cost of spray applications. Certainly, small trees and lightly foliated canopies do not require large sprayers. Reduction of fan speed is a practical method for decreasing pesticide waste and application cost in spraying small and low-density trees. It should be noted that sprayers must be re-calibrated if they are used at lower fan speeds.

Nozzle Arrangement

In Florida citrus applications, it has been a common practice to direct 2/3 of the spray volume to the upper half of the tree and 1/3 to the lower half. However, this practice is no longer recommended when spraying small trees or using large airblast sprayers. The 2/3-1/3 nozzle arrangement has shown no significant improvement in overall spray deposition or pest control as compared to 1/2-1/2 (uniform) nozzle arrangement. The latter may also minimize errors in nozzle selection. Sprayer air deflectors, nozzle orientation and number of nozzles should be adjusted to match the size and shape of the canopy and minimize spray wastage (see Figure l).

For low volume rates (less than 100 gal/acre), reducing the number of nozzles and using smaller disc and core sizes rather than spraying at higher ground speeds may improve spray deposition. For high-volume rates (greater than 250 gal/acre),

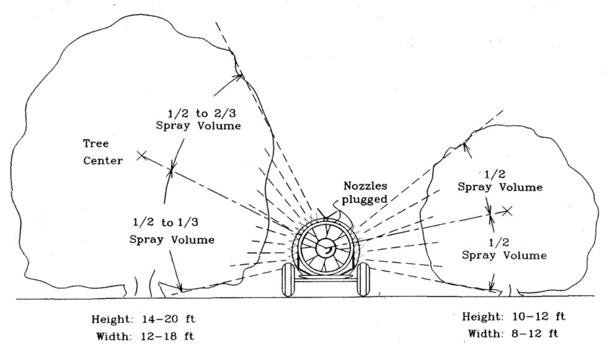

Figure 1. Recommended nozzle arrangement and spray volume distribution.

increasing the number of nozzles and spraying at higher ground speeds instead of using fewer large disc and core sizes, may give higher deposition efficiency. Deposition efficiency of mid-volume rates (100-250 gal/acre) is less sensitive to these application variables.

Sprayer Calibration

Application errors can originate from either incorrect tank concentration of the pesticides (mixing error) or incorrect sprayer output per unit area (calibration error). The latter may be due to travel speed, nozzle pressure, or the use of improper, defective, and worn nozzles. However, by proper matching of the sprayer discharge rate, swath width, and travel speed, calibration errors can be mitigated. Sprayer calibration can be carried out by: a) determining the amount of the tank mix used to spray a known area; b) operating the sprayer in a fixed place and measuring the amount of discharged liquid (water) for a specified time; or c) collecting the nozzle discharge and determining the output for a time period. Application rate is then determined by calculations. If the rate is not acceptable, then sprayer and/or application parameters need adjustment. See UF/IFAS Circular 1435, Calibration of Airblast Sprayers (http://edis.ifas.ufl.edu/AE238), for details. The use of high capacity nozzles at low pressures to achieve low-volume application rates, one-sided calibration of the sprayer for two-sided operations and vice versa, calibration at closed pressure settings and intermittent operation of the nozzles can introduce errors in application rates. Sprayers using positive displacement pumps (diaphragm, piston, etc.) have more potential for application error compared to sprayers using centrifugal pumps, particularly at high volume rates.

Application Rate Adjustment

The maximum per acre rate of pesticides, given in this publication, is based on applications to mature citrus trees that have reached containment size (hedgerow status). Smaller trees can be sprayed with the same concentration of agrichemical, but using fewer nozzles (see Figure l). This should provide spray deposition approximately comparable to that of mature trees, with lower spray volume and active ingredient per acre.

The spray volume rate can be calculated from Equation 1:

$$VR = \frac{(495) \times (SO)}{(GS) \times (RS)}$$

where:
VR = Spray Volume Rate (gal/acre)
SO = Sprayer Output (gal/min)
GS = Ground Speed (mile/h)
RS = Tree Row Spacing (ft)

Equation 1.

The actual applied rate of pesticides for small trees would be a fraction of the maximum rate per acre, as shown in Equation 2.

$$PRS = \frac{(VRS) \times (PRM)}{(VRM)}$$

where:
PRS = Actual applied rate of pesticides for small trees (pt or lb/acre)
VRS = Spray volume rate for small trees (gal/acre)
VRM = Spray volume rate for mature trees (gal/acre)
PRM = Pesticide rate for mature trees (pt or lb/acre)

Equation 2.

Further reduction in spray usage may be obtained by shutting the nozzles (manually or automatically) when passing by the gaps between adjacent trees. The above adjustments match the sprayer output with the tree size while providing adequate spray coverage and lowered off-target spray movement.

Spray Volume and Ground Speed

Lower spray volumes can deposit as much or more pesticide on the canopy than dilute rates. This is because spray runoff from leaf surface decreases and more material remains on the canopy. Lower volumes involve the use of smaller-orifice nozzles that provide smaller droplet sizes and more uniform spray distribution on the leaf surface. However, variability of spray distribution within the canopy and drift potential increases as spray volume decreases. With existing spray equipment and for average size trees, a volume rate of about 250 gal/acre may be a good compromise for controlling most pests of economic importance, except some scale insects. The volume rate may be reduced further if higher pesticide concentration is more important than thorough wetting for controlling certain pests (see the label for limitations).

Increasing the ground speed can reduce the runoff from leaf surfaces in locations close to the sprayer. This effect can result in increased spray deposition and may be more pronounced with high volume rates and large orifice nozzles. On the other hand, hard-to-reach areas of the canopy may not have enough exposure for adequate spray penetration and deposition. The higher the sprayer air volume, the more potential it may have for high-speed applications. However, variability of deposition increases at higher speeds, a ground speed of about 2.5 mph may be a reasonable speed for most citrus sprayers operating under average grove conditions.

Weather Conditions

The effectiveness and safety of spray applications largely depend on weather conditions during the application. High wind velocities can decrease spray coverage while increasing the variability of deposition and off-target drift. Pesticides should not be applied when wind velocity exceeds 10 mph or when it blows toward an adjacent residential area or susceptible crop. While calm conditions are desirable for spray deposition, temperature inversion may create severe drift problems. Vertical movement of the air during unstable weather conditions can increase the chance of spray drift, but dilution of the drift cloud makes it less serious than concentrated drift clouds generated under inversion conditions.

The size of the water-based droplets reduces constantly as they move from the sprayer. The evaporation becomes faster under hot and dry conditions and may become critical for low volume applications. By using larger orifice nozzles and/or lower spray pressures, droplet size can be increased and spray drift decreased.

LV/ULV Spray Guidance

The U.S. Environmental Protection Agency and the Florida Department of Agriculture and Consumer Services allow the use of a pesticide on an agricultural site in a manner which results in the application of the same or less amount of active ingredient(s) to the site as specified on the product label but with less diluent than is specified on the product label if certain conditions are met:

1. The use of less diluent is not specifically prohibited on the product label, and;
2. All other precautionary statements regarding product mixing, loading, and preparation, application methods, rates, frequency, pre-harvest intervals, tolerances, field re-entry intervals, protective clothing or equipment requirements, product packaging and transportation requirements, and storage and disposal practices are complied with.

Typically, pesticide product labels include advisory language encouraging the user to apply the product in a solution of sufficient volume to achieve complete coverage of foliage. Coupled with this language, manufacturers suggest a range of spray volumes necessary to achieve adequate foliage coverage. However, unless the label contains language such as "do not use less than 'x' gallons of water volume per acre", it is acceptable for the grove manager to use less volume than suggested by the range on the label. Growers should be cautious, however, and recognize the fact that crop damage occurring as a result of the use of less diluent than recommended on the label is solely their responsibility. Therefore, it is strongly recommended that this use pattern be tested on a small crop area before implementing widespread application.

SPRAYING WEEDS

Herbicide Applicators

Herbicides are mostly applied with boom sprayers. These sprayers work on the same principles as tree sprayers and consist of a tank, pump, flow (pressure) regulator, agitation system (hydraulic or mechanical), nozzle manifold (boom), and a set of nozzles. However, compared to tree sprayers, herbicide applicators normally are equipped with smaller PTO-driven pumps (centrifugal, roller, or piston) and lower hydraulic pressures (10-50 psi).

The pump should be resistant to wear and corrosion. It must have enough capacity (gal/min) and pressure (psi) for both nozzle output and hydraulic agitation. This requires at least 20% greater capacity beyond the combined nozzle demand. Most pump manufacturers recommend not exceeding 70-80% of the pump's capacity for continuous operations. Agitation is more critical for wettable powders and water dispersible formulations. Inadequate mixing of these products could result in non-uniform concentration of the herbicide in the tank, nozzle clogging problems, and over-dose or under-dose output from nozzles. Over-dosing of blocks with young trees can result in severe stunting and/or phytotoxicity. Tanks without sharp corners minimize the chance for product settlement. Herbicide applicators equipped with mechanical agitation systems perform better than those with hydraulic agitation but they are more expensive.

Regardless of differences in the design and price of the sprayers, the success of weed control largely depends on the choice of herbicide, timing of the application, and proper maintenance, calibration, and use of the equipment. More information on the selection and timing of herbicide application can be found in UF/IFAS fact sheet HS-107 Weeds. The following sections provide information on proper nozzle selection and calibration of herbicide applicators.

Nozzle Selection

In Florida, nearly all boom sprayers are equipped with hydraulic pressure nozzles. These nozzles are available in many sizes, shapes, and materials and may be color-coded or identified by a number. A typical nozzle assembly consists of nozzle body, strainer (screen), tip (orifice), and cap (tip holder). Strainers vary in mesh size based on the size of the nozzle orifice (opening). Smaller openings (lower capacities) require finer mesh to minimize nozzle clogging.

Nozzles differ significantly in durability, flow rate, droplet spectrum, and distribution pattern. Brass and nylon nozzle tips are the least expensive but are relatively soft and wear rapidly; therefore, they are not suitable for spraying abrasive tank mixes such as wettable powders. On the other hand, ceramic and hardened stainless steel tips are more expensive but have excellent wear life and are very resistant to abrasive and corrosive chemicals.

For a given nozzle type, flow rate (capacity) depends on the tip orifice size and operating pressure. In nozzle manufacturers' catalogs, nozzle flow rates (GPM) are usually listed for a few selected pressures (PSI). It should be noted that all the tabulations are based on spraying water. When calibrations are based on water, the equivalent GPM of the heavier or lighter solutions should be calculated from Equation 3.

$$GPM_w = GPM_s \ x \ CF$$

where:

GPM_w = Equivalent nozzle capacity for water

GPM_s = Desired nozzle capacity of heavier or lighter solution

CF = Correction factor for solution density

= square-root of specific gravity (SG)

Equation 3.

Most nozzles perform satisfactorily around 30 PSI; however, recommended pressure of each specific nozzle should be determined from its manufacturer's catalog. If the desired GPM could not be obtained at the recommended pressure, then the pressure should be adjusted. Since nozzle flow rate varies in proportion to square root of the pressure (Equation 4), only minor adjustment could be achieved by changing pressure. Major adjustments require the use of smaller or larger nozzles.

$$PSI_2 = PSI_1 \ x \left[\frac{GPM_2}{GPM_1}\right]^2$$

where:

PSI_2 = Correct operating pressure

PSI_1 = Recommended pressure

GPM_2 = Desired flow rate

GPM_1 = Flow rate at PSI_1

Equation 4.

Droplet size spectra and distribution patterns of nozzles vary substantially and largely depend on nozzle type, flow rate, operating pressure, and spray angle. Flat fan nozzles generate relatively smaller droplets, whereas drift-reducing nozzles produce larger droplets. Extended-range nozzles adjust the droplet size over a wide range of nozzle pressures. Flooding nozzles produce a wide spray angle and flat pattern. Nozzles with solid or hollow cone spray patterns may also be used in some post-emergence herbicide applications.

Most of the available nozzles have spray angles ranging from 65° to 140°. The nozzle's designated angle corresponds to the rated pressure. Spray angle increases or decreases at higher or lower pressures, respectively. Nozzle wear not only increases the angle and output, but it also distorts spray distribution pattern to some extent.

Spray Distribution

Unlike tree sprayers, nozzles used on herbicide equipment should be uniform (same type, material, capacity, and spray angle). Using a variety of nozzles on a boom results in uneven distribution patterns. However, herbicide applicators used in citrus may include an off-center nozzle tip (at the end of the boom) to extend the coverage beyond the end of the boom and cover the area around the tree trunk. It is normally mounted on a swivel body, a few inches beyond the last main nozzle.

Nozzles that generate tapered edge patterns (e.g., flat fan) need some pattern overlap in order to obtain a reasonably uniform distribution across the spray swath. The amount of pattern overlap depends on nozzle spacing, boom height, and spray angle.

Nozzles used on citrus herbicide applicators are normally mounted on 10-12 inch centers and operated at a height of 12-14 inches. Smaller spray angles require higher nozzle (boom) height in order to achieve acceptable pattern overlap (usually 30-50%). Some nozzles may require 50-100% pattern overlap. Nozzle catalogs normally specify optimum spacing, height, and overlap for each nozzle type. For a given nozzle flow rate, an improper boom height setting or vertical movement of the boom will result in uneven distribution (untreated bands or larger than desired treatment areas) across the spray swath.

Herbicide Sprayer Calibration

Application rate depends on nozzle flow rate (function of orifice size and operating pressure), number of nozzles, row spacing, and ground speed. Equations 5 and 6 show the relationships among these factors for broadcast and directed sprays, respectively.

$$GPA = \frac{GPM \ x \ 5{,}940}{GS \ x \ NS}$$

or

$$GPM = \frac{GPA \ x \ GS \ x \ NS}{5{,}940}$$

where :

GPA = Application rate (gal/acre)

GPM = Flow rate per nozzle (gal/min)

GS = Sprayer ground speed (mile/h)

NS = Nozzle spacing (in)

Equation 5.

$$GPA = \frac{GPM \ x \ NN \ x \ 495}{GS \ x \ RS}$$

where :

NN = Number of nozzles

RS = Row spacing (ft)

Equation 6.

The quality of calibration depends on accuracies of the nozzle flow rate and ground speed measurements. To ensure accurate nozzle flow rate, flow regulator(s) and pressure gauge(s) must be in working order. The latter should have a reasonable range in order to provide accurate reading of the system pressure. Since nozzle capacity tabulations (in catalogs) are based on pressure at the nozzles, the gauge closer to the nozzles should be used in calibration. In-line strainers and nozzle filters (screens) should be clean in order to avoid any restriction in the nozzle flow.

Calibration procedures are similar to those mentioned for tree sprayers. They include: a) determining the amount of the tank mix (gallons) used to spray a known area (acres), b) operating the sprayer in a fixed position and measuring the amount of discharged water (tank refill gallons) for a given time (minutes), or c) determining the nozzle discharge rate (gal/min). If the calculated GPA was not the same as the desired GPA, then ground speed and/or nozzle pressure should be changed. The latter could only be used for minor adjustments. See UF/IFAS Factsheet HS-1012, Citrus Herbicide Boom Sprayer Calibration (http://edis.ifas.ufl.edu/HS252), for more information.

The following equation (7) determines the ground speed. See UF/IFAS Circular 1435, Calibration of Airblast Sprayers, for detail of procedures for ground speed measurement.

$$GS = \frac{TD \ x \ 60}{TT \ x \ 88}$$

where :

GS = Sprayer ground speed (mile/h)

TD = Travel distance (ft)

TT = Travel time (sec)

Equation 7.

BEST MANAGEMENT PRACTICES (BMPs) FOR PESTICIDE APPLICATIONS:

As mentioned earlier, pesticides can be expected to be effective if the 'right material' is applied at the 'right amount', on the 'right target', at the 'right time', with the 'right sprayer', under the 'right weather' conditions. Read the product label for specific information, pertinent regulations, and safety recommendations. Follow the federal, state, and local government laws and regulations carefully. The following general BMP guidelines apply to most spraying practices.

1. Identify the nature of the pest that is causing the problem (consult with an extension agent, plant pathologist, entomologist, etc.).

a. Determine whether it is located on the canopy or in the root system, outside or inside the canopy, and on upper or lower leaf surface.

b. In case of weeds, identify their types and whether they are spread under tree or in the row middle.

c. Learn about pest biology and its interaction with tree and fruit growth stage.

d. Find out if the pest could be controlled by cultural practices and/or non-chemical methods.

e. If chemical control is the preferred method, what category of pesticides may provide the desired solution?

2. Find out about the timing of the application.

a. Scout the grove/field to establish the pest threshold level.

b. Determine the optimum application window for effective control of the pest.

c. Try to apply the pesticide when the pest is most vulnerable. It is very important to deal with pests at the most vulnerable biological or growth stages in their life cycles. Pesticide applications beyond the optimum window are likely to result in less efficacious pest control.

d. Make sure the application will be completed several hours before a rain shower.

3. Select an appropriate pesticide (insecticide, fungicide, herbicide, etc.).

a. Make sure the selected pesticide has been proven effective against the specific pest and registered for the intended use.

b. Choose the least persistent and lowest toxicity pesticide.

c. Make sure it will not generate phytotoxicity or pest resistance under intended use conditions.

d. Check its compatibility with other products that will be included in the tank mixture.

e. Learn about proper storage of the material to prevent chemical breakdown and fire hazards (read the label).

f. Some pesticides specify the use of specific adjuvants to improve physical and/or chemical properties of the product. Select the right adjuvant and use it at the right rate in order to achieve the desired objective.

4. Determine the right amount (application rate) for the intended application.

a. This information could be found on the label. It is usually specified as gallons, pints, pounds, or ounces of the product per grove or treated acre.

b. Consider the application time and the target growth stage for suggested dose transfer.

c. Adjust the rate according to the tree size, row spacing, pest pressure, and other pertinent factors.

5. Use properly calibrated equipment.

a. Make sure the sprayer is in good working condition. Examine the pump, nozzles, manifolds, hoses, regulators, pressure gauges, etc. Clean all nozzle screens and inline strainers.

b. Read the label for limitations on spray droplet size (spray classification category) and suggestions for drift mitigation near the sensitive areas. Select the right nozzle type, size, and pressure for the job. Make sure the selected nozzles are consistent with the label's spray quality recommendation (i.e., very fine, fine, medium, coarse, very coarse, or extremely coarse). Use nozzles that generate a minimal percentage of smaller drift-prone droplets at the specified operating pressure.

Consider using “low-drift” nozzles when available.

c. Check nozzle spacing, nozzle angle, and boom height to make sure there is sufficient pattern overlap for uniform spray coverage.

d. In airblast applications, adjust the orientations of nozzles and air deflectors to direct the spray cloud onto the tree canopy only.

e. Check the functionality of the sprayer agitation system (mechanical or hydraulic). Some formulations have specific mixing requirements.

f. Be careful about the order of material addition into the tank. Usually, adjuvants are added before pesticides. Refer to the product label for recommended mixing order.

g. Use only clean water free from dirt, sand, algae, etc. Algae quickly clog the strainers and nozzles. Sand and other abrasive particles expedite pump and nozzle wear. Other contaminants may react with the pesticide and reduce its effectiveness. Water pumped from ditches or ponds should be filtered before filling the tank.

h. Examine the uniformity of the tank mixture. This is more critical when using wettable powder or dry formulations, particularly with irregularly shaped tanks featuring sharp corners. Pre-mixing the chemicals in a small container could help uniform mixing in the sprayer tank.

i. Follow the label recommendations for avoiding drift from highly volatile formulations.

j. Use an appropriate ground speed based on the tractor/sprayer capabilities, terrain conditions, boom stability requirements, etc. Make sure the intended ground speed will be achieved during the application. Check the tire pressure.

k. Monitor the operation of the nozzles during the application. Observe the output pattern of nozzles periodically. Nozzle clogging and changes in nozzle pressure and ground speed will affect the actual application rate.

l. Carry spare nozzles, screens, washers, etc. for quick adjustments/repairs in the field.

6. Apply pesticide under right weather conditions.

a. If possible, avoid spraying during hot, dry, or windy weather conditions. Night-time applications could increase spray deposition and reduce drift.

b. Avoid spraying during stable (inversion) conditions (early morning and early evening) when there is little or no vertical mixing of the air. These conditions generate concentrated drift clouds and increase the chance of drift fallout.

c. Stop spraying a few hours before rain showers. Allow sufficient time for sprays to dry and form reasonably durable deposits.

d. Monitor wind direction and do not spray when there are sensitive crops/areas immediately downwind.

e. Keep records of air temperature, relative humidity, wind speed, and wind direction. These records as well as equipment and application information may be very helpful in dealing with drift-related litigation.

7. Follow the safety instructions.

a. Read the most recent product label. Look at the signal word (Danger, Warning, Caution). It gives an indication of the pesticide toxicity level.

b. Learn about the environmental hazards (effects on wildlife, water resources, etc.) associated with using the product.

c. Read the label for recommended personal protective equipment (coveralls, boots, gloves, goggles, respirators, etc). Wear protective clothing during equipment calibration, loading, mixing, spraying, and clean up.

d. Before mixing and applying the pesticide, learn about using the first aid and medical treatment in an accident.

e. Minimize the spray mixture leftover and rinsate (mix right amount as needed).

f. If possible, use formulations that are packaged in returnable or refillable containers.

g. Clean the sprayer shortly after task completion. This practice not only increases equipment life, it also reduces the chance of pesticide cross contamination.

h. Rinse and dispose the pesticide containers properly as directed by the label.

i. Follow all safety guidelines related to the operation of the equipment (tractor, sprayer, nurse tank, etc.).

j. If available, use sprayers equipped with a canopy sensing system (UF/IFAS Factsheet HS-872, Sensor-Controlled Spray Systems for Florida Citrus, http://edis.ifas.ufl.edu/HS140). The system helps to direct the pesticide to the intended target more precisely, thereby reducing pesticide wastage and environmental contamination.