UNIVERSITY OF FLORIDA

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EXTENSION

Institute of Food and Agricultural Sciences

Calibration of Airblast Sprayers[1]

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Airblast sprayers are the most commonly used spray equipment in citrus foliar applications. They may be tractor-mounted, tractor-drawn (PTO- or engine-driven), or self propelled, but all of them use high velocity air to transport the droplets from the nozzles to the tree canopy. The droplets are entrained in a turbulent air flow and their deposition depend on the air flow characteristics of the sprayer, droplet size spectrum, operating parameters, pesticide properties, canopy structure, and weather conditions. A proper combination of the above factors can improve the coverage and increase the efficiency of pesticide application.

Application error can originate from either incorrect tank mix concentration (mixing error) or incorrect sprayer output per unit area/tree (calibration error). The latter may be due to errors in travel speed, nozzle pressure, or the use of improper, defective or worn nozzles. Nonetheless, by matching of the sprayer discharge rate, travel speed, and swath width, calibration errors can be mitigated.

Calibration Methods

Sprayer calibration can be carried out by three methods:

1. Determining the amount of the tank mix used to spray a known area. Then, application rate (GPA) can be calculated by using the following equations.

$$\text{GPA} = [\text{GA}] \div [\text{AS}] \tag{1}$$

Equation 1.

or

$$\text{GPA} = [\text{GA} \times 43{,}560] \div [\text{TS} \times \text{RS} \times \text{NT}] \tag{2}$$

Equation 2.

GPA = Gallons per acre (gpa)

GA = Gallons applied or spray volume (gal)

AS = Area sprayed (acre)

TS = Tree spacing within the row (ft)

RS = Tree row spacing (ft)

NT = No. of trees sprayed.

43,560 = No. of sq ft in one acre

2. Operating the sprayer in a fixed position and measuring the volume of the sprayed water (from both sides) for a specified time. Then, GPA can be calculated by using the following equations.

$$GPM = [GA] \div [MIN] \qquad (3)$$

Equation 3.

$$GPA = [GPM \times 495] \div [MPH \times RS] \qquad (4)$$

Equation 4.

where,

GPM = Sprayer discharge (output) rate from both sides, in gallons per minute (gpm)

MIN = Time elapsed in spraying the above volume (min)

MPH = Ground speed in miles per hour (mph)

495 = [43,560 sq ft/1 acre] x [1 mile/5,280 ft] x [60 min/1 hour]

3. Operating the sprayer in a fixed position and determining the flow rate of the nozzles. Again, application rate (GPA) can be calculated by equations 3 and 4. If the flow rate of each nozzle is measured separately, then the sprayer discharge rate (GPM) will be the sum of individual flow rates:

$$GPM = GPM_1 + GPM_2 + \cdots GPM_n \qquad (5)$$

Equation 5.

If the calculated rate (GPM) is not acceptable, then the nozzles and/or application parameters (pressure and/or speed) should be adjusted.

Nozzle Selection and Arrangement

Sprayer nozzles should be selected based on the desired volume rate, operating pressure, droplet size spectrum, and compatibility with the sprayer. In general, high volume applications require large orifice nozzles, increasing the pressure reduces the droplet size, small droplets are more drift-prone, and every nozzle cannot be used on every sprayer. A good collection of nozzles can provide more flexibility in nozzle selection. The word "nozzle" refers to hydraulic pressure nozzles only and air-shear nozzles or rotary atomizers are not used in the following examples.

The nozzles should be arranged to match the size, shape, and density of the canopy. In Florida citrus applications, it is common practice to direct 2/3 of the total spray volume to the upper half of the tree canopy and 1/3 to the lower half (Figure 1). To accomplish this, 2/3 of the spray should be discharged from the nozzles located on upper half of the nozzle manifold. The nozzles and air guide vanes should be oriented so that the spray cloud is properly directed toward the desired canopy location. Some of the upper nozzles may be plugged or shut off when spraying small trees.
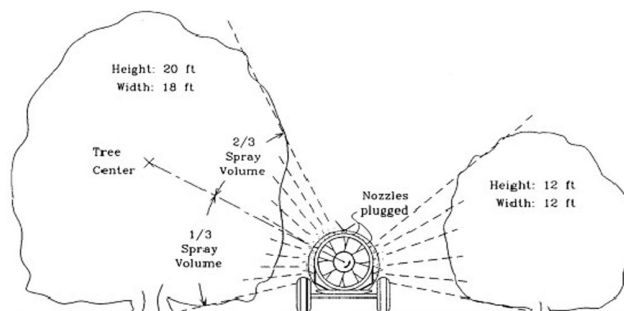
Figure 1. Recommended nozzle arrangement and spray volume distribution for citrus applications.

Given the desired application rate (GPA), sprayer ground speed (MPH), and tree row spacing (RS), nozzle selection involves the following steps:

a) Determine the output of the sprayer (GPM) by using the following equation:

$$GPM/side = [GPA \times MPH \times RS] \div [990] \qquad (6)$$

Equation 6.

b) Multiply the "GPM/side" by 2/3 (0.67) to obtain the discharge rate from nozzles in the upper half of the nozzle manifold.

c) Multiply the "GPM/side" by 1/3 (0.33) to obtain the discharge rate from the lower half of the nozzle manifold.

d) Determine the number of nozzles you will be using on the upper and lower sections of the manifold.

e) Divide the discharge rate from the upper nozzles (step "b") by the number of nozzles in that section to obtain the approximate GPM for each nozzle.

f) Repeat step "e" for the lower nozzles to obtain the approximate GPM for each nozzle in the lower section.

g) Use nozzle manufacturer's charts to select the nozzles for each section. You may not find the exact desired GPM on the chart. Choose nozzles that have capacities close to the desired rate.

h) Multiply the GPM capacities of the selected nozzles by the corresponding number of nozzles. Add the GPM in the upper and lower sections to obtain the total nozzle capacity for each side of the sprayer (GPM/side).

i) Compare the above "GPM/side" with the desired rate calculated in step "a". Check the sprayer calibration as in methods 1, 2, or 3. Increase or decrease the pressure to achieve the desired GPM. If you do not adjust the pressure, then you may change the ground speed to achieve the desired application rate (GPA).

Example 1

(NOTE: the volume, speed, pressure, number of nozzles, and tree spacings given in the examples should not be construed as IFAS recommendation).

A grower wants to spray 500 gpa at 1.5 mph, using an airblast sprayer. The tree rows are set at 25 ft spacing, the sprayer uses 10 TeeJet ceramic disc-core nozzles per side, and desired nozzle pressure is about 150 psi. Select the appropriate nozzles for the application.

a) GPM/side = [500 x 1.5 x 25] ÷ [990] = 18.94 gpm

b) 18.94 x 0.67 = 12.63 gpm (total discharge rate from upper nozzles)

c) 18.94 x 0.33 = 6.31 gpm (total discharge rate from lower nozzles)

d) The grower will be using 5 nozzles in the upper half and 5 nozzles in the lower half of the manifold.

e) 12.63 ÷ 5 = 2.52 gpm (approx. capacity of each nozzle in upper section)

f) 6.31 ÷ 5 = 1.26 gpm (approx. capacity of each nozzle in lower section)

g) The TeeJet nozzle chart (Table 1) indicates that you need to select either D12-45 (2.69 gpm) or D7-46 (2.73 gpm) for the upper section and D6-45 (1.15 gpm) or D7-45 (1.35 gpm) for the lower section. You would probably select D12-45 and D7-45 for the upper and lower sections, respectively.

h) 2.69 x 5 = 13.45 gpm (total capacity for the upper nozzles)

1.35 x 5 = 6.75 gpm (total capacity for the lower nozzles)

13.45 + 6.75 = 20.2 gpm (total selected capacity for each side)

i) The selected capacity (GPM_1) is larger than the desired capacity (GPM_2). Since nozzle flow rate varies with the pressure (Equation 7), the output capacity can be decreased by decreasing the nozzle pressure.

$$PSI_2 = PSI_1 \times [GPM_2 \div GPM_1]^2 \qquad (7)$$

Equation 7.

where,

PSI_2 = New pressure (psi)

PSI_1 = Desired pressure (psi)

Then

$$PSI_2 = 150 \text{ x } [18.94 \div 20.20]^2 = 132 \text{ psi}$$

If you prefer not to lower the pressure and accept the 20.2 gpm, then you must increase the ground speed in order to achieve the desired application rate of 500 gpa. The speed can be adjusted by the following equation.

$$MPH_2 = MPH_1 [GPM_1 \div GPM_2] \qquad (8)$$

Equation 8.

Then

$$MPH_2 = 1.5 \text{ x } [20.20 \div 18.94] = 1.6 \text{ mph}$$

Considering the spray angle, droplet size, nozzle availability, and also to achieve gradual transition from the upper to lower section, you may select the following nozzles for the above application (Table 2).

Example 2

A grower wants to apply 250 gpa at 1.5 mph to trees set at 25 ft row spacing. His sprayer has 13 submanifolds per side. Each submanifold has 3 nozzle bodies (13 x 3 = 39 potential nozzle outlets per side). After a preliminary trial, he decides to use only 10 submanifolds per side. Using the FMC nozzle chart (Table 3), select the appropriate nozzles for a working pressure of about 140 psi.

a) GPM/side = [250 x 1.5 x 25] ÷ [990] = 9.47 gpm

b) 9.47 x 0.67 = 6.34 gpm (total GPM of upper nozzles)

c) 9.47 x 0.33 = 3.13 gpm (total GPM of lower nozzles)

d) The grower decides to use 2 nozzles on each submanifold in the upper section (5 x 2 = 10 nozzles) and only one nozzle per submanifold in the lower section (5 x 1 = 5 nozzles).

e) 6.34 ÷ 10 = 0.63 gpm (approx. GPM of each nozzle in upper section)

f) 3.13 ÷ 5 = 0.63 gpm (approx. GPM of each nozzle in lower section)

g) The following nozzles may be an appropriate selection for the application (Table 4).

Ground Speed Measurement

The measurement must be carried out on a ground surface similar to the grove condition. The sprayer should be hitched to the tractor. Sprayer tank should be about half full and, if the sprayer is PTO-driven, it must be operated at the rated speed.

1. Known Distance Method:

Mark out a 100-300 ft course. Drive at a constant speed (MPH) and use a stopwatch to record the time (SEC) it takes to travel the course. Then,

$$MPH = [D \text{ x } 0.68] \div [SEC] \qquad (9)$$

Equation 9.

where,

D = Course length or distance traveled (ft)

SEC = Travel time (sec)

0.68 = [1 mile/5,280 ft] x [3,600 sec/1 hour]

Example:

If it takes 46.7 seconds to travel 200 ft, the ground speed is: MPH = [200 x 0.68] ÷ [46.7] = 2.9 mph

2. Trees Passed Method:

Measure the tree spacing within the row (TS). Drive at a constant speed (MPH). Count the number of trees passed (NT) and record the travel time (MIN). Then,

$$MPH = [TS \text{ x } NT] \div [MIN \text{ x } 88] \qquad (10)$$

Equation 10.

where,

88 ft/min = 1 mile/hour

<u>Example:</u>

It takes 2.75 minutes to pass 50 trees that are spaced at 15 ft. The ground speed is:

MPH = [15 x 50] ÷ [2.75 x 88] = 3.1 mph

Note: When measuring the speed on a sloped course, you should drive both uphill and downhill and take the average.

Spray Volume Measurement

The amount of liquid in the tank can be approximated by using a calibrated stick or a sight gauge. This requires parking the tractor and sprayer on a level ground and ensuring proper tire inflation pressure during the measurement. However, the accuracy of the measurement will vary with liquid level in the tank. A supply tank, equipped with a calibrated flowmeter, can provide more accurate measurements. The latter can be used to refill the tank and determine the amount of sprayed liquid for calibration methods 1 and 2 (see Equations 1 and 3).

To be able to use the third calibration method, the liquid discharged from each nozzle should be collected for 15-30 seconds at the desired operating pressure. A graduated cylinder or similar container and a stopwatch may be used for this purpose. It is also possible to attach some tubing to the nozzles and collect the discharge from all nozzles simultaneously. By directing the flow to different containers, it is possible to use the actual spray fluid in the calibration and obtain more accurate flow rate measurements.

It should be noted that all nozzle chart tabulations are based on spraying water. The GPM of the heavier or lighter solutions should be corrected as follows:

$$GPM_w \quad GPM_s \text{ x } CF \qquad\qquad (11)$$

Equation 11.

where,

GPM_w = Equivalent nozzle capacity for water

GPM_s = Nozzle capacity of heavier or lighter solution

CF = Correction factor for solution density = square root of specific gravity (SG).

<u>Example:</u>

If a spray solution weighs 10.1 lbs/gal and the desired output from the nozzles is 15 gpm, what would be the equivalent GPM for water (8.34 lbs/gal).

SG = 10.1 ÷ 8.34 = 1.21 (specific gravity of the solution)

CF = sq root 1.21 = 1.1 (correction factor)

GPM_w = 15 x 1.1 = 16.5 gpm (corrected GPM)

The corrected GPM is the capacity that should be used for nozzle selection from the charts.

In summary, the accuracy of the sprayer calibration depends on the accuracies of the speed and discharged volume measurements. Any error in any stage of the measurements can result in some error in the application rate. Therefore, sprayers should be calibrated carefully to avoid overdose or underdose applications.

Table 1. Truncated TeeJet nozzle chart. See TeeJet Agricultural Spray Products Catalog for complete list.

Nozzle		Nozzle Capacity (gpm) at pressure of							Spray Angle	
Disc No.	Core No.	40 psi	60 psi	80 psi	100 psi	150 psi	200 psi	300 psi	40 psi	80 psi
D5	45	0.45	0.55	0.64	0.71	0.86	0.99	1.22	73°	76°
D6	45	0.58	0.72	0.83	0.93	1.15	1.33	1.64	79°	81 °
D7	45	0.68	0.84	0.97	1.11	1.35	1.57	1.94	86°	87°
D8	45	0.84	1.04	1.21	1.35	1.68	1.94	2.40	90°	90°
D10	45	1.10	1.3 5	1.57	1.77	2.18	2.50	3.10	93 °	93 °
D12	45	1.36	1.68	1.95	2.20	2.69	3.11	3.80	100°	102°
D4	46	0.56	0.68	0.78	0.88	1.07	1.23	1.52	29°	33 °
D5	46	0.77	0.94	1.10	1.25	1.50	1.73	2.13	39°	42°
D6	46	1.10	1.35	1.58	1.73	2.16	2.50	3.06	48°	50°
D7	46	1.39	1.72	1.97	2.22	2.73	3.15	3.85	53°	56°
D8	46	1.84	2.25	2.62	2.93	3.60	4.17	5.05	60°	62°

Table 2. Nozzle selection for Example 1.

Nozzle location	Disc-core No.	GPM @ 150 PSI	Total GPM
Top 10	D7-46	2.73	
9	D7-46	2.73	
8	D7-46	2.73	
7	D7-46	2.73	
6	D6-46	2.16	Upper Manifold 13.08
5	D5-46	1.50	
4	D7-45	1.35	
3	D7-45	1.35	
2	D7-45	1.35	
Bottom 1	D6-45	1.15	Lower Manifold 6.70
Measured output rate: 19.78 gpm @ 150 psi Calibrated output rate: 18.94 gpm @ 138 psi *The new pressure (138) is calculated by Equation 7. Make sure your sprayer pump is capable of delivering the desired GPM at the calculated PSI. Check the calibration.			

Table 3. Truncated FMC nozzle chart. See FMC nozzle catalog for complete selection.

Nozzle		Nozzle Capacity (gpm) at pressure of					
Disc. No.	Core No.	100 psi	120 psi	140 psi	160 psi	180 psi	200 psi
3	1 Hole	0.23	0.25	0.26	0.29	0.31	0.33
	2 Hole	0.32	0.35	0.38	0.41	0.44	0.46
	3 Hole	0.45	0.49	0.53	0.57	0.61	0.65
4	1 Hole	0.31	0.34	0.37	0.40	0.42	0.45
	2 Hole	0.43	0.48	0.52	0.55	0.58	0.62
	3 Hole	0.66	1.00	1.08	1.14	1.21	1.29
5	2 Hole	0.63	0.71	0.76	0.81	0.86	0.90
	3 Hole	1.20	1.30	1.41	1.50	1.60	1.68

Table 4. Nozzle selection for Example 2.

Nozzle location	Disc/core No.			GPM 140 PSI				Total GPM
Top 13	X,	X ,	X	0 +	0	+	0	0
12	X,	X ,	X	0 +	0	+	0	0
11	5/2,	3/3,	X	0.76 + 0.53		+	0	1.29
10	5/2,	3/3,	X	0.76 + 0.53		+	0	1.29
9	5/2,	3/3,	X	0.76 + 0.53		+	0	1.29
8	5/2,	3/3,	X	0.76 + 0.53		+	0	1.29
7	5/2,	3/3,	X	0.76 + 0.53		+	0	<u>1.29</u>
			X					6.45 Upper Manifold
6	5/2,	X ,	X	0.76 +	0	+	0	0.76
5	5/2,	X ,	X	0.76 +	0	+	0	0.76
4	3/3,	X ,	X	0.53 +	0	+	0	0.53
3	3/3,	X ,	X	0.53 +	0	+	0	0.53
2	3/3,	X ,	X	0.53 +	0	+	0	0.53
Bottom 1	X,	X ,	X	0 +	0	+	0	<u>0</u>
	(X=plugged nozzle)							<u>3.11</u> Lower Manifold
								9.56 gpm @ 140 psi
								9.47 gpm @ 137 psi*

* The new pressure (137) is calculated by Equation 7.
Make sure your sprayer pump is capable of delivering the desired GPM at the calculated PSI.
Check the calibration.