Selecting the Right Type and Size of Nozzles for Effective Spraying in Orchards and Vineyards

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Although nozzles are some of the least expensive components of a sprayer, they hold a high value in their ability to influence sprayer performance. Nozzles meter the amount of liquid sprayed per acre and how efficiently, effectively, and uniformly the pesticide being sprayed deposits on the target canopy. Nozzles also help determine droplet size, affecting both target coverage and the risk of spray drift. Nozzles come in a wide variety of types and sizes. The best nozzle for a given application will maximize efficacy, minimize spray drift, and allow compliance with label requirements such as the application rate (gallons per acre) and the size of the spray droplets.

Flat-fan nozzles (Figure 1) are the dominant type of nozzles found on sprayers used for field crops and vegetables. Sprayers used in vineyards and orchards are usually equipped with hollow-cone nozzles (Figures 2–4). However, in other parts of the world—especially Europe—the low-drift versions of flat-fan nozzles are becoming as widely used as the hollow-cone nozzles that are used for spraying orchards. This European trend is not as prevalent for vineyard spraying.

In the U.S., the most common hollow-cone nozzle used in orchard and vineyard sprayers is the disc-core type (Figure 3). The disc is paired with a core to achieve a desired flow rate, spray angle, and spray pattern (Figures 5a and 5b). The flow rate of the nozzle is determined by the size of the hole in the disc (Figure 6) and the spray pressure. Some of the holes seen on cores, as shown in Figure 7, are slanted which creates the swirling action as the liquid flows through the holes which eventually creates a cone pattern when the liquid is discharged from the nozzle. The cores with a straight (unslanted) hole drilled in the center of the plate (as shown in the third core from the left in Figure 7) change the hollow cone pattern to a full cone pattern as shown in Figures 2 and 5b. The components of a disc-core type of nozzle are shown in Figure 9.

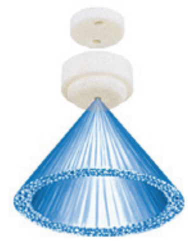

Figure 5a. The uppermost core with two holes creates a hollow-cone spray.

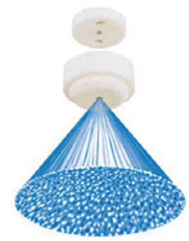

Figure 5b. The uppermost core with three holes creates a solid or full-cone spray.

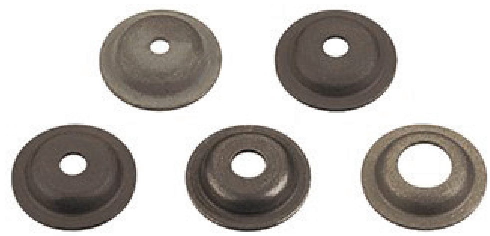

Figure 6. Five discs with different sized holes. Larger holes result in a greater flow rate and bigger droplet size at the same pressure.

Figure 1. Flat-fan nozzle.

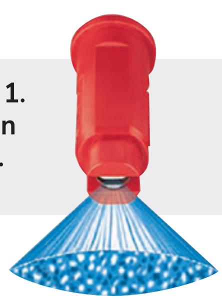

Figure 2. Disc-core, full-cone nozzle.

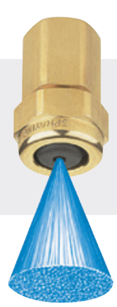

Figure 3. Disc-core, hollow-cone nozzle.

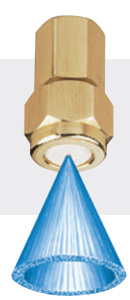

Figure 4. One-piece, hollow-cone nozzle.

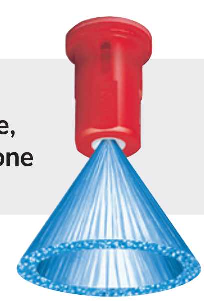

Figure 7. Cores with slanted holes that are used in disc-core nozzles to spray a cone pattern. The four cores with a hole in the center of the plate spray a full-cone pattern. The core in the middle without a hole in the center of the plate sprays a hollow-cone pattern.

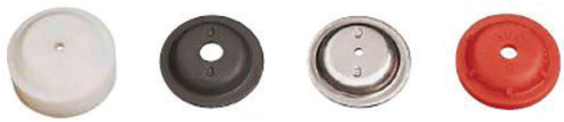

Figure 8. Discs used in disc-core nozzles.

The cores shown in Figure 7 and the discs shown in Figure 8 may come in different materials such as ceramic, hardened stainless steel, stainless steel, brass, or polymer/nylon (listed in the order of their resistance to wear). It's recommended to use either the ceramic or the hardened stainless-steel discs or cores, especially with dry pesticide products. Dry pesticides cause excessive wear on parts made from brass, polymer, or nylon. Be careful when handling ceramic discs and cores. If dropped on hard surfaces they may chip or break. For proper assembly and performance, the disc and core selected must be of the same material.

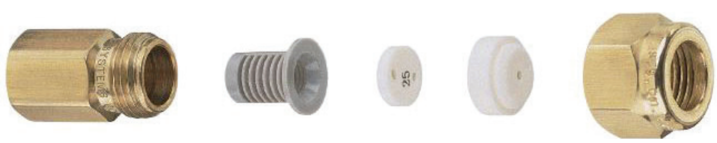

Figure 9. The individual components of a disc-core nozzle in their order of assembly.

One-piece hollow-cone nozzles (Figure 10) have been gaining wide acceptance in more recent years for several reasons:

- Both the disc and the core are one piece, which eliminates the chance of losing one of them.
- The numbers on a disc or core in a disc-core type of hollow-cone nozzle are small and hard to read.
- Ceramic versions of the disc or core can easily break when dropped on hard surfaces.
- The one-piece versions of hollow-core nozzles are color coded (a different color for each flow rate) which avoids the risk of unintended mixing of different nozzle sizes on the sprayer.

Choosing the Appropriate Nozzle Size

Once the best nozzle for a specific spraying situation is determined, select the appropriate nozzle size to match the application rates (gal/acre) prescribed by product labels under various operating conditions (spray pressures and travel speeds). The apps developed by most of the major nozzle manufacturers provide the exact nozzle flow rate required for any given set of application parameters. The apps also identify a specific set of nozzle recommendations for the application parameters. To find these apps, simply visit the App Store in your smart phone or tablet and search "Spray Nozzle Calculator," or some other key words related to nozzle size selection. Searches using the name of nozzle companies may also produce results. However, some apps are not user-friendly and do not account for droplet size requirements when recommending nozzles. Although the apps and tables in catalogs may expedite the nozzle size selection process, it is recommended that spray applicators understand the procedure and math that nozzle manufacturers use to generate table values in their catalogs and nozzle recommendations in their apps. The procedure nozzle manufacturers use to generate numbers in their catalog tables and in their apps is explained below. Use the following steps to determine the exact nozzle flow rate (GPM) required to meet spray application parameters.

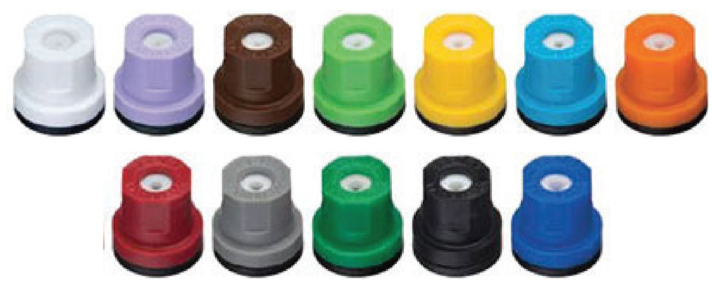

Figure 10. One-piece, color-coded, hollow-cone nozzles, each of which have their own flow rate. Flow rates increase from 0.053 gal/min (the white nozzle on the left, with the smallest orifice) to 0.49 gal/min (the blue nozzle on the right with the largest orifice) at the rated spray pressure of 40 psi.

When selecting the appropriate nozzle size, three pieces of information are needed:

- MPH: The travel speed of the sprayer in miles per hour.
- GPA: The intended or recommended application rate in gallons sprayed per acre of land.
- W: Distance in feet between two rows of an orchard or grapevine to be treated. Note: If more than one row is treated using a multi-row sprayer, then multiply the row spacing in feet by the number of rows.

These values can be entered in the equation below to determine the total liquid discharged from all nozzles on the sprayer in one minute, which is referred to as gallons per minute (GPM).

$$GPM = \frac{GPA \times MPH \times W}{495}$$

EXAMPLE

You would like to spray product X in your orchard or vineyard using a conventional airblast sprayer with five nozzle outlets on each side of the sprayer. The sprayer will travel every row and will spray rows on both side of the sprayer during each pass. You would like to use disc-core, hollow-cone nozzles (manufactured by TeeJet) on each side of the sprayer (total 10 nozzles). You are intending to travel at a speed (MPH) of 4 miles per hour during spraying. The distance between the rows (W) across from each adjacent rows of orchard or grapevine is 8 feet. You would like to operate the sprayer at a pressure of 80 to 100 psi to meet the droplet size class recommendation on the label. The label recommends that the application rate (GPA) should be 50 gallons per acre. What size disc-core, hollow-cone nozzle will provide the desired gal/min flow rate (GPM) to satisfy the required 50 gallons per acre application rate?

$$\text{GPM} = \frac{\text{Application Rate (GPA) x MPH x Row Spacing (ft)}}{495}$$

$$\text{GPM} = \frac{\text{50 GPA x 4 MPH x 8 ft}}{495}$$

$$\text{GPM} = \frac{50 \times 4 \times 8}{495} = \frac{1600}{495} = \text{3.23 gal/min nozzle flow rate for 10 nozzles}$$

$$\text{GPM per nozzle} = \frac{3.23}{10} = \text{0.32 GPM}$$

GPM per nozzle = 0.32

Upon completion of this calculation, open the nozzle manufacturer's catalog or visit their website and check the page where flow rate information is given for the disc-core, hollow-cone nozzles. The table will look like Table 1 shown on the next page. Columns one and two provide the identification numbers of discs and cores, respectively. Starting with the fourth column, each number shown in a red rectangle represents the flow rate of each nozzle in gallons per minute (GPM) at different operating pressures.

1. Read along the pressure row at the top of the table to locate 80 and 100 psi.
2. Scan the numbers under the columns for 80 and 100 psi (contained within the blue rectangle) until you see 0.32 GPM, or a value close to it.
3. After you locate 0.32, scan to the left side of the row to find which disc and core combination will satisfy this flow rate.
4. In this case, 0.32 is listed twice under 100 psi column.
5. When you scan to the left you will see that either the hollow cone nozzle with a D6 disc and DC23 core, or a D2 disc with a DC45 core is the nozzle that will satisfy all the requirements.
6. Alternatively, the nozzle with a D4 disc and a DC23 core may also satisfy the need if you want to operate the sprayer at 200 psi. However, increasing the pressure is likely to cause the droplets to get smaller. This is likely to increase the drift of droplets.

If a one-piece, hollow-cone nozzle from the same manufacturer is chosen (instead of the disc-core type), then follow the same steps shown above to reach the required nozzle-flow rate of 0.32 GPM. Again, to determine which nozzles deliver 0.32 GPM, review the GPM information for nozzles in the company catalog or on their website. As shown on Table 2, two nozzles can satisfy the requirements: TXR80015VK operated at 200 psi or TXR80017VK operated at 160 psi. Notice that the droplet size class in both cases will be Very Fine (VF). Precautions should be taken to minimize the drift of droplets.

More information on selecting the nozzle type and size are outlined in the Ohio State University Extension publication FABE-528, "Selecting the Best Nozzle for the Job." (**ohioline.osu.edu/factsheet/fabe-528**).

Summary and Recommendations

Nozzles are typically the least costly items on a sprayer, but they play a key role in ensuring that the final outcomes of a spraying job:

- Achieve maximum efficacy from the pesticide applied.
- Reduce the off-target (drift) movement of pesticides.

Pesticides are most effective if the rates on labels are used during application. This can be achieved only if the sprayer has the right nozzle type, the appropriate nozzle size, and if the sprayer is operated properly.

Other than selecting the best nozzle type and size, there are many other important tasks that contribute to realizing the best results from spraying pesticides in orchards and vineyards:

- Carefully read and follow the recommendations provided on the pesticide label, in the nozzle manufacturers' catalogs, and in the sprayer operator's manuals.
- Choose the right equipment. Choose a sprayer that delivers the required application rate with droplets of the desired size to the target with minimum loss of spray on the ground and in the air.

Table 1. A typical page showing flow rate (GPM) of different disc-core, hollow-cone nozzles operated under different spray pressures (PSI).

			GPM									
			10 PSI	20 PSI	30 PSI	40 PSI	60 PSI	80 PSI	100 PSI	150 PSI	200 PSI	300 PSI
D1	DC13	.031″	—	—	.059	.066	.078	.088	.097	.115	.128	.152
D1.5	DC13	.036″	—	.057	.067	.075	.088	.098	.110	.127	.142	.167
D2	DC13	.041″	—	.064	.075	.08	.10	.11	.12	.14	.16	.18
D3	DC13	.047″	—	.071	.08	.09	.11	.12	.13	.16	.18	.20
D4	DC13	.063″	.070	.09	.11	.12	.14	.16	.17	.20	.23	.27
D1	DC23	.031″	—	—	.064	.072	.080	.096	.107	.124	.139	.164
D1.5	DC23	.036″	—	.064	.076	.086	.103	.117	.130	.155	.175	.210
D2	DC23	.041″	—	.078	.092	.10	.13	.14	.16	.19	.21	.25
D3	DC23	.047″	.065	.087	.10	.12	.14	.16	.18	.21	.24	.28
D4	DC23	.063″	.082	.113	.14	.15	.19	.21	.23	.28	.32	.38
D5	DC23	.078″	.095	.13	.16	.18	.22	.25	.28	.34	.38	.46
D6	DC23	.094″	.112	.15	.19	.21	.26	.29	.32	.39	.45	.54
D1	DC25	.031″	—	—	.088	.101	.122	.138	.156	.185	.210	.255
D1.5	DC25	.036″	—	—	.118	.135	.162	.185	.205	.245	.280	.33
D2	DC25	.041″	—	.12	.14	.16	.19	.22	.25	.29	.34	.41
D3	DC25	.047″	.10	.14	.17	.19	.23	.26	.29	.35	.40	.48
D4	DC25	.063″	.15	.21	.25	.29	.35	.40	.45	.54	.62	.75
D5	DC25	.078″	.18	.25	.30	.35	.42	.48	.54	.65	.75	.90
D6	DC25	.094″	.23	.32	.39	.44	.54	.62	.70	.85	.97	1.19
D7	DC25	.109″	.26	.37	.45	.52	.63	.73	.81	.98	1.18	1.37
D8	DC25	.125″	.31	.43	.53	.61	.75	.89	.97	1.19	1.36	1.68
D10	DC25	.156″	.38	.54	.65	.76	.93	1.07	1.21	1.48	1.71	2.1
D12	DC25	.188″	.46	.61	.80	.93	1.15	1.32	1.47	1.81	2.09	2.55
D14	DC25	.219″	.51	.72	.88	1.03	1.26	1.47	1.65	2.02	2.34	2.89
D1	DC45	.031″	—	—	—	.125	.148	.170	.190	.225	.257	.310
D1.5	DC45	.036″	—	—	.14	.16	.20	.23	.25	.31	.35	.43
D2	DC45	.041″	—	.14	.18	.20	.25	.28	.32	.38	.44	.53
D3	DC45	.047″	—	.17	.20	.23	.28	.33	.36	.44	.51	.62

Table 2. A typical page showing flow rate (GPM) of different disc-core, hollow-cone nozzles operated under different spray pressures (PSI).

Nozzle	Strainer	GPM												
		30 PSI	40 PSI	50 PSI	60 PSI	70 PSI	80 PSI	90 PSI	100 PSI	120 PSI	140 PSI	160 PSI	180 PSI	200 PSI
TXR800053VK	100	0.046	0.053	0.059	0.064	0.069	0.073	0.077	0.081	0.089	0.095	0.101	0.107	0.113
		VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF
TXR800071VK	50	0.062	0.071	0.079	0.086	0.093	0.099	0.105	0.110	0.120	0.129	0.138	0.146	0.153
		F	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF
TXR8001VK	50	0.087	0.100	0.111	0.121	0.131	0.139	0.147	0.155	0.169	0.182	0.194	0.205	0.216
		F	F	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF
TXR80013VK	50	0.116	0.133	0.148	0.162	0.174	0.186	0.196	0.207	0.225	0.243	0.259	0.274	0.288
		F	F	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF	VF
TXR80015VK	50	0.131	0.150	0.167	0.182	0.196	0.209	0.221	0.232	0.254	0.273	0.291	0.308	0.324
		F	F	F	F	F	VF	VF	VF	VF	VF	VF	VF	VF
TXR80017VK	50	0.145	0.167	0.185	0.202	0.218	0.232	0.246	0.258	0.282	0.303	0.323	0.342	0.360
		F	F	F	F	VF	VF	VF	VF	VF	VF	VF	VF	VF
TXR8002VK	50	0.174	0.200	0.223	0.243	0.261	0.279	0.295	0.310	0.338	0.364	0.388	0.410	0.432
		F	F	F	F	VF	VF	VF	VF	VF	VF	VF	VF	VF
TXR80028VK	50	0.240	0.275	0.306	0.334	0.359	0.383	0.405	0.426	0.465	0.500	0.533	0.564	0.594
		F	F	F	F	F	VF	VF	VF	VF	VF	VF	VF	VF
TXR8003VK	50	0.260	0.300	0.335	0.367	0.396	0.423	0.449	0.473	0.517	0.558	0.597	0.633	0.667
		F	F	F	F	F	F	VF	VF	VF	VF	VF	VF	VF
TXR80036VK	50	0.309	0.356	0.398	0.435	0.470	0.502	0.532	0.561	0.614	0.663	0.708	0.751	0.791
		F	F	F	F	F	F	VF	VF	VF	VF	VF	VF	VF
TXR8004VK	50	0.347	0.400	0.447	0.489	0.528	0.564	0.598	0.630	0.690	0.745	0.796	0.843	0.889
		F	F	F	F	F	F	VF	VF	VF	VF	VF	VF	VF
TXR80049VK	50	0.423	0.488	0.545	0.597	0.644	0.688	0.730	0.769	0.842	0.909	0.971	1.03	1.09
		F	F	F	F	F	F	F	F	F	F	F	VF	VF

- Select the right type and size of nozzle to achieve maximum pesticide deposit and coverage on the target. Utilize the apps developed by sprayer/nozzle manufacturers when selecting nozzles.
- Operate the nozzles at a pressure that allows them to produce the spray quality (droplet size) recommended on the product label.
- Calibrate the sprayer to ensure that the recommended amount of pesticide (based on the product's label) is applied.
- Understand how to calculate the correct amount of chemical product that needs to be mixed in the tank. This is explained in Ohio State University Extension Publication FABE 530, "How Much Chemical Product Do I Need to Add to My Sprayer Tank?" (**ohioline.osu.edu/factsheet/fabe-530**)
- Check the sprayer setup to ensure that the pesticide is distributed evenly on all parts of the canopy.
- If more than one type of chemical is added to the sprayer tank, check the products' labels to ensure that mixing is done in the appropriate order.
- Keep spray drift in mind. Take precautions to reduce it to minimum. Consider using drift-reduction nozzles.
- Slow down when spraying. Spray coverage at the inner parts of the vines is usually improved at slower speeds. Travel speeds

that are too slow, however, are likely to result in excessive use of pesticides and increased spray drift.

- Take advantage of technological advancements in spray technology, such as variable-rate and site-specific application that reduces pesticide consumption.
- Conduct tasks such as sprayer calibration and mixing/loading of chemicals in areas that do not have ground and/or surface water pollution.
- Be safe. Wear protective clothing, goggles, rubber gloves, and respirators as recommended on the product's label when calibrating the sprayer, performing the spraying, and cleaning the equipment.

The following websites are excellent sources of additional information on spraying orchards and vineyards:

- **platform.innoseta.eu**
- **sprayers101.com/airblast101**

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