

Selecting the Best Nozzle for the Job

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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 unit area, controlling application rate, as well as variability of spray over the width of the sprayer boom. Nozzles also influence droplet size, affecting both target coverage and spray drift risk.

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 application rate (gallons per acre) and spray droplet size. Selecting the best nozzle requires careful consideration of all the factors listed below:

- **Sprayer operation parameters**
 - Application rate, spray pressure, travel speed
- **Type of chemical sprayed**
 - Herbicides (soil incorporation, pre/post emergence)
 - Insecticides
 - Fungicides
 - Fertilizers and growth regulators
- **Mode of action of chemical** (spray coverage requirement)
 - Systemic
 - Contact
- **Application type** (broadcast, band, directed, air assisted)

- **Target crop** (field crops, vegetables, vineyard, shrubs and trees, etc.)
- **Spray drift risk**

Nozzle selection

Nozzle type

Each nozzle type is designed for a specific type of target and application. For example, a nozzle designed for broadcast spraying is not good for spraying pesticides over a narrow band. Luckily, most nozzle manufacturers' catalogs have charts showing which nozzle **type** will be best for a specific job. Check the websites of nozzle manufacturers to reach their catalogs. For more information, contact your county Extension office.

Nozzle size

Nozzle manufacturers' catalogs provide tables and charts showing application rates (gallons per acre or gpa), given a nozzle's flow rate (gallons per minute or gpm) delivered at various pressures (psi) and travel speeds (mph). These tables are useful tools for selecting the appropriate nozzles, pressure and speed to spray chemicals at application rates prescribed by product labels. However, the charts are only for a limited number of travel speed and nozzle spacing situations. There may be situations where the charts will not provide information associated with your sprayer setup (nozzle



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spacing) and operating conditions (travel speed and spray pressure). The Apps developed by most of the major nozzle manufacturers can provide you the exact nozzle flow rate required for any given set of application parameters, and identify a specific set of nozzle recommendations for the given application parameters. To find these Apps, simply visit the App Store in your smart phone or tablet and do a search under “Spray Nozzle Calculator”, or some other key words related to nozzle size selection. You may also want to do a search under the name of the nozzle company from which you are interested in buying the nozzles. However, some Apps are not user friendly and sometimes they do not take into account the droplet size requirements when recommending nozzles. Although the Apps and tables in catalogs may expedite the nozzle size selection process, it is best to understand the procedure and the math nozzle manufacturers use to generate the values listed in tables and to recommend nozzles in their Apps. The procedure used by the nozzle manufacturers to generate numbers in tables and in their Apps is explained below. By following the steps mentioned below, you should be able to determine the exact nozzle flow rate (gpm) required for your spray application parameters. Once the exact nozzle flow rate is determined, you can then look at the catalog to select the nozzle that will provide you the flow rate at a practical pressure setting.

Steps to select the proper nozzle size:

The following steps must be taken to determine the nozzle flow rate (gpm):

Step 1. Select the application rate in gallons per acre (gpa). This is a management decision you will have to make based on pesticide label recommendations, field conditions and water supply.

Step 2. Select a practical and safe ground speed in miles per hour (mph).

Step 3. Determine the spray width per nozzle (W).
 For broadcast applications, W = nozzle spacing (distance between two nozzles on the boom) in inches.
 For band spraying, W = band width in inches.
 For directed spraying, W = row spacing in inches (or band width) divided by the number of nozzles per row (or band).

Step 4. Determine the flow rate (gpm) required from each nozzle by using the following equation:

$$gpm = \frac{gpa * mph * W}{5940}$$

(5940 is a constant to convert gpa, mph and inches to gpm).

Step 5. Select a nozzle size from the manufacturer’s catalog that will give the flow rate (gpm) determined in Step 4 when the nozzle is operated within the recommended pressure range. If a nozzle of this size is not available, change the travel speed in the equation above and determine the new flow rate required.

For example: You want to spray a pre-emergence herbicide at 15 gpa, at a speed of 8 mph. The distance between the nozzles on the boom is 20 inches. The herbicide label requires a spray quality of “Medium.” What should be the flow rate of the nozzle you will choose?

$$gpm = \frac{gpa * mph * W}{5940}$$

Since this is a broadcast application (pre-emergence), W is the distance between nozzles (W = 20”). Filling in the variables yields the following calculation:

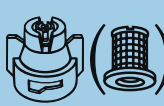

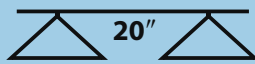
$$gpm = \frac{15 \text{ gpa} * 8 \text{ mph} * 20 \text{ in.}}{5940} = 0.4 \text{ gpm}$$

This means, to apply 15 gpa at a speed of 8 mph with this sprayer setup, we need to select a nozzle with a flow rate of 0.4 gpm.

Now, we go to the nozzle catalog, and find a nozzle that will give us a flow rate of 0.4 gpm, while operating the sprayer at an applicable pressure and traveling at 8 mph.

Catalogs have charts for each nozzle, similar to the one shown on the next page. The first column gives the color code of the nozzle (which indicates flow rate), nozzle ID number, and the appropriate filter type for the nozzle. Column 2 gives the pressure range at which the nozzle should be operated. Column 3 gives the spray quality, a measure of spray droplet size (fine, medium, coarse, etc.) produced at different pressure settings. Columns 4 and 5 give the flow rate of nozzles in gallons per minute and ounces per minute, respectively, at different pressure settings. Column 6 gives gallons per acre application rate at different travel speed settings.

First, we need to find the best **type** of nozzle for our application. In their catalog, the nozzle manufacturer recommends a **flat-fan** pattern type nozzle for broadcast application of pre-emergence herbicides. Then we find a chart associated with the nozzle type recommended. The chart shown happens to be for that type of a nozzle. Now we proceed with the process to determine the appropriate **size** of the nozzle.

Column 1 	Column 2  PSI	Column 3 DROP SIZE		Column 4 CAPACITY ONE NOZZLE IN GPM	Column 5 CAPACITY ONE NOZZLE IN OZ./MIN.	Column 6 GPA							
		80°	110°			20" 							
						4 MPH	5 MPH	6 MPH	8 MPH	10 MPH	12 MPH	15 MPH	20 MPH
XRC80015 (100)	15	M		0.092	12	6.8	5.5	4.6	3.4	2.7	2.3	1.8	1.4
	20	M		0.11	14	8.2	6.5	5.4	4.1	3.3	2.7	2.2	1.6
	30	F		0.13	17	9.7	7.7	6.4	4.8	3.9	3.2	2.6	1.9
	40	F		0.15	19	11.1	8.9	7.4	5.6	4.5	3.7	3.0	2.2
	50	F		0.17	22	12.6	10.1	8.4	6.3	5.0	4.2	3.4	2.5
	60	F		0.18	23	13.4	10.7	8.9	6.7	5.3	4.5	3.6	2.7
XRC8002 XRC11002 (50)	15	M	M	0.12	15	8.9	7.1	5.9	4.5	3.6	3.0	2.4	1.8
	20	M	F	0.14	18	10.4	8.3	6.9	5.2	4.2	3.5	2.8	2.1
	30	M	F	0.17	22	12.6	10.1	8.4	6.3	5.0	4.2	3.4	2.5
	40	F	F	0.20	26	14.9	11.9	9.9	7.4	5.9	5.0	4.0	3.0
	50	F	F	0.22	28	16.3	13.1	10.9	8.2	6.5	5.4	4.4	3.3
	60	F	F	0.24	31	17.8	14.3	11.9	8.9	7.1	5.9	4.8	3.6
XRC110025 (50)	15		M	0.15	19	11.1	8.9	7.4	5.6	4.5	3.7	3.0	2.2
	20		M	0.18	23	13.4	10.7	8.9	6.7	5.3	4.5	3.6	2.7
	30		F	0.22	28	16.3	13.1	10.9	8.2	6.5	5.4	4.4	3.3
	40		F	0.25	32	18.6	14.9	12.4	9.3	7.4	6.2	5.0	3.7
	50		F	0.28	36	21	16.6	13.9	10.4	8.3	6.9	5.5	4.2
	60		F	0.31	40	23	18.4	15.3	11.5	9.2	7.7	6.1	4.6
XRC8003 XRC11003 (50)	15	M	M	0.18	23	13.4	10.7	8.9	6.7	5.3	4.5	3.6	2.7
	20	M	M	0.21	27	15.6	12.5	10.4	7.8	6.2	5.2	4.2	3.1
	30	M	F	0.26	33	19.3	15.4	12.9	9.7	7.7	6.4	5.1	3.9
	40	M	F	0.30	38	22	17.8	14.9	11.1	8.9	7.4	5.9	4.5
	50	M	F	0.34	44	25	20	16.8	12.6	10.1	8.4	6.7	5.0
	60	F	F	0.37	47	27	22	18.3	13.7	11.0	9.2	7.3	5.5
XRC8004 XRC11004 (50)	15	C	M	0.24	31	17.8	14.3	11.9	8.9	7.1	5.9	4.8	3.6
	20	C	M	0.28	36	21	16.6	13.9	10.4	8.3	6.9	5.5	4.2
	30	M	M	0.35	45	26	21	17.3	13.0	10.4	8.7	6.9	5.2
	40	M	M	0.40	51	30	24	19.8	14.9	11.9	9.9	7.9	5.9
	50	M	F	0.45	58	33	27	22	16.7	13.4	11.1	8.9	6.7
	60	M	F	0.49	63	36	29	24	18.2	14.6	12.1	9.7	7.3
XRC8005 XRC11005 (50)	15	C	M	0.31	40	23	18.4	15.3	11.5	9.2	7.7	6.1	4.6
	20	C	M	0.35	45	26	21	17.3	13.0	10.4	8.7	6.9	5.2
	30	C	M	0.43	55	32	26	21	16.0	12.8	10.6	8.5	6.4
	40	M	M	0.50	64	37	30	25	18.6	14.9	12.4	9.9	7.4
	50	M	M	0.56	72	42	33	28	21	16.6	13.9	11.1	8.3
	60	M	F	0.61	78	45	36	30	23	18.1	15.1	12.1	9.1
XRC8006 XRC11006 (50)	15	C	C	0.37	47	27	22	18.3	13.7	11.0	9.2	7.3	5.5
	20	C	C	0.42	54	31	25	21	15.6	12.5	10.4	8.3	6.2
	30	C	M	0.52	67	39	31	26	19.3	15.4	12.9	10.3	7.7
	40	C	M	0.60	77	45	36	30	22	17.8	14.9	11.9	8.9
	50	C	M	0.67	86	50	40	33	25	19.9	16.6	13.3	9.9
	60	C	M	0.73	93	54	43	36	27	22	18.1	14.5	10.8

In our example above, the equation in Step 4 resulted with a flow rate of 0.4 gpm. Now, we look at Column 4 (gpm per nozzle) to determine the nozzle that provides us 0.4 gpm. Using the chart, we see that the nozzles XRC8004 or XRC11004 (shown in red) provide 0.4 gpm flow rate at 40 psi operating pressure. This nozzle also happens to provide Medium (designated with “M”) spray quality as recommended on the herbicide label. Under these operating conditions, this sprayer should apply 15 gpa at 8 mph as we expected. The validation of this is also evident on the chart. If you look at Column 6, choose 8 mph ground speed, the nozzle we selected will spray approximately 15 gallons per acre (14.9 gpa shown on the chart) at 8 mph travel speed and 40 psi spray pressure.

There may be multiple numbers of nozzles that can satisfy the 0.4 gpm flow rate requirements. However, they may not satisfy the desired spray quality and/or desired travel speed. It may be necessary to adjust pressure and/or travel speed according to nozzle selection. For example, the Brown XRC8005 nozzle is capable of producing 0.4 gpm, and achieving 15 gpa at 8 mph, if the spray pressure is reduced to about 25 psi. Similar calculations can be made using the equation below to come up with other GPM (flow rate) and PSI (pressure) combinations to satisfy the required 15 gpa application rate:

$$\frac{GPM_1}{GPM_2} = \frac{\sqrt{PSI_1}}{\sqrt{PSI_2}}$$

In this example, reducing the pressure to 25 psi alters the spray quality to “Coarse,” violating the label recommendation.

When changing pressure is not an appropriate choice, the only other practical option is to change the travel speed. There is an inverse linear relationship between the travel speed (mph) and the application rate (gpa). The relationship is expressed by the equation:

$$\frac{GPA_1}{GPA_2} = \frac{MPH_2}{MPH_1}$$

Or

$$GPA_1 * MPH_1 = GPA_2 * MPH_2$$

Using the relationship above, we can determine that increasing the travel speed to 9.9 mph and keeping the sprayer operating at 40 psi will yield 15 gpa, as described below:

The chart on the previous page indicates when using XRC11005, **GPA₁** = 18.6 at 8 mph (**MPH₁**) at 40 psi. We want to find out what the new travel speed (**MPH₂**) should be to achieve 15 gpa (**GPA₂**).

Using the equation above:

$$18.6 \text{ GPA} * 8 \text{ MPH} = 15 \text{ GPA} * \text{MPH}_2$$

$$\text{MPH}_2 = \frac{18.6 \text{ GPA} * 8 \text{ MPH}}{15 \text{ GPA}} = 9.9 \text{ mph}$$

However, increasing travel speed to 9.9 mph may not be practical or safe. When changes to pressure or travel speed as dictated by the equations above are neither practical nor safe, it may be necessary to select a different nozzle.

In this example, it looks like the best nozzles to use for our application situation are XRC8004 or XRC11004, both providing 0.4 gpm at 40 psi. The only difference between these two nozzles is in the angle of spray pattern: one produces an 80 degree fan pattern (XRC8004), while the other one (XRC11004) produces a 110 degree fan pattern. Due to the difference in the angle of the spray pattern, each of these nozzles require different boom heights to obtain proper overlap between two adjacent nozzles.

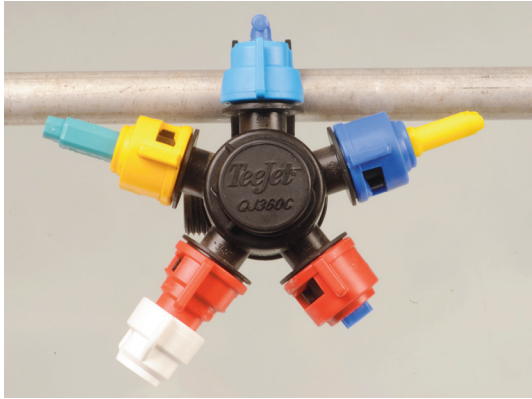
Calibrate the sprayer

Selecting the right type and size of a nozzle is not sufficient to end up with accurate, effective and efficient application of chemicals sprayed. Changes in ground conditions (tilled, untilled, grass, wet, dry), and the topography of the field sprayed (flat, sloped) will affect the ground speed which is one of the variables used in determining the correct nozzle size. Nozzle orifices wear out with time causing larger flow rates and distorted spray patterns than when they were new. The gpm flow rate values given in catalogs or in Apps are based on spraying water only. Spraying solutions with higher densities than water (most spray solutions are) will affect the flow rates of nozzles at the same spray pressure. For the reasons mentioned above, sprayers should be calibrated frequently, especially when the field conditions change, to determine the actual application rate. Calibration is easy, and there are many ways to do it. Regardless of the method chosen, three measurements will be taken: actual ground speed, the distance between nozzles, and nozzle flow rate for a given length of time. One easy method is explained in an OSU Extension Publication (AEX 520) listed in the references at the end of this publication.

Keep several types of nozzles on the boom

Remember that one specific type of nozzle will not be best for all applications. For this reason, it is best to have several types and sizes of nozzles on the boom

so that you can switch to the “best” nozzle choice for a given spraying job. As shown in the pictures below, there are various types of sprayer components and setups you can buy to configure your boom so the new set up allows you to easily switch from one nozzle to another instantly.



Keep spray drift in mind when selecting nozzles

One of the major problems challenging pesticide applicators is spray drift, which is defined as movement of pesticides by wind from the application site to an off-target site. Drift is influenced by many factors which are discussed in detail in two OSU Extension publications (Bulletin 816 and AEX-525) listed in the references at the end of this publication. Equipment, especially the nozzles, used to spray pesticides play a significant role in generating as well as reducing spray drift. In nozzle catalogs, you can see a number of different nozzles of the same **type**, in terms of spray pattern. For example, one can find nozzles within the same “flat-fan” category classified as “low-drift.” Research conducted at Ohio State and elsewhere clearly indicate that nozzles labeled as “low-drift” significantly reduce spray drift as discussed in OSU Extension publication AEX-523 (listed in the references below). If drift is, or becomes a concern, it may be best to switch from a conventional flat-fan nozzle to a “low-drift” flat-fan nozzle with the

same flow rate. Therefore, it is best to have more than one type of a “flat-fan” pattern nozzle on the boom.

Summary and conclusions

Nozzles are typically the least costly items on a sprayer, but they play a key role in the final outcome from a spraying job: achieving maximum efficacy from the pesticide applied while reducing the off-target (drift) movement of pesticides to minimum. Pesticides work well if the rates on labels are achieved during application. This can be achieved only if the right nozzle type and the proper size of the nozzles are on the sprayer, and the sprayer is operated properly.

Although the Apps and tables in catalogs may expedite the nozzle size selection process, it is best to understand the process and the math nozzle manufacturers use to generate the values listed in tables, and to generate nozzle recommendations in their Apps. This procedure, explained in this publication, hopefully will help you to determine the exact nozzle flow rate (gpm) required for your spray application parameters, while highlighting some other important parameters such as spray pressure, droplet size, spray coverage on the target, and drift, all of which should be given serious consideration when selecting the best nozzle for a spraying job.

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