Circular 1305

Nozzle Selection for Sprayers Equipped with Pulse Width Modulation Technology

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- Introduction
- Duty Cycle and Ground Speed
- PWM Nozzle Selection Example
- Steps to Use a PWM Nozzle Selection Chart
- Other Useful Tools for PWM Nozzle Selection
- Additional Considerations for PWM Nozzle Selection
- Resources for PWM Nozzle Selection

Introduction

Pulse width modulation (PWM) technology is becoming a standard option on most new agricultural sprayers because of its ability to precisely regulate both flow rate and pressure over a wide range of travel speeds. Through this improved control, sprayers equipped with PWM technology allow more precise and efficient pesticide applications compared to sprayers with traditional flow-based control systems. Detailed information on PWM technology, including its main components, operation, and benefits, is available in the UGA Extension Circular 1277, *Pulse Width Modulation Technology for Agricultural Sprayers* (https://extension.uga.edu/publications/detail.html?number=C1277).

One of the main considerations when utilizing a PWM-equipped sprayer is proper nozzle selection. Nozzle selection for PWM sprayers differs from that of conventional sprayers (without PWM) and requires applicators to consider some additional factors to ensure proper PWM system operation during pesticide applications.

Duty Cycle and Ground Speed

The first step in sizing a nozzle for a PWM system is to understand the duty cycle of the system—a key parameter used to regulate the flow rate. The duty cycle is the proportion of time that the solenoid is open or on—in other words, the percentage of time the nozzle is spraying. For most commercial systems, typical duty cycle ranges are between 20% and 100%. A 100% duty cycle means a spray nozzle is fully open and delivering maximum flow, while a nozzle operating at a 20% duty cycle will deliver about one-fifth of the maximum flow. During application, the PWM system automatically adjusts the duty cycle to maintain the target application rate (gallons per acre or GPA) as ground speed variations occur while spraying. While lower duty cycles (< 20%) are possible, they typically are not recommended because of inconsistent spray quality and pattern.

Besides determining a target rate and droplet size for your intended application, an additional parameter used for nozzle selection for PWM sprayers is average ground speed. The average ground speed determines the minimum and maximum speed at which an operator can spray without exceeding the selected nozzle's pressure rating. Since the duty cycle of the PWM system is directly related to ground speed, the goal is to select a nozzle that will operate between 60% and 80% duty cycle at this average speed. This means that the nozzle will be open roughly two-thirds of the time and the PWM system will have enough flexibility to adjust the duty cycle up or down if the travel speed increases or decreases below the average speed.

Once the operator has selected an average speed and determined the minimum and maximum speeds (for 20% and 100% duty cycles, respectively) for the intended application, PWM nozzle selection/tabulation charts can be used in the same way they are used to select a spray nozzle for traditional sprayers without PWM.

PWM Nozzle Selection Example

The information shared above for selecting a nozzle for a PWM sprayer can be better explained by working through an example application:

A grower wants to select a nozzle for a PWM sprayer to apply 10 GPA at an average ground speed of 10 mph. The nozzle spacing on the sprayer is 20 in. and the desired droplet size for this application is a "Medium" spray classification.

Assuming 10 mph as an average speed around a desired 75% duty cycle, we will first calculate the minimum and maximum ground speeds for this application using the 20% and 100% duty cycles, respectively. Remember as discussed previously, the selected duty cycle value (75% in this case) for these calculations can be anywhere within the 60% and 80% range. The exact value does not change the results considerably, so choosing any number within that range is acceptable for these calculations.

Ground speed (mph) at min. or max. duty cycle = average ground speed (mph) / target duty cycle, typically .75 × min. or max. duty cycle

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Ground speed at 20% duty cycle:

2.7 mph = 10 (mph) / .75 × .20

Ground speed at 100% duty cycle:

13.3 mph = 10 (mph) / .75 × 1.0

Now using the target parameters known for this application, we will use a PWM nozzle selection chart provided by one of the nozzle manufacturers (Figure 1) to select a nozzle best suited for this application.

Tip Size	Gauge (PSI)	Nozzle (PSI)	BPDF	BP	SD	DF	TCP	7.5 GPA				10 GPA				12.5 GPA				15 GPA			
								Min		- Max		Min		- Max		Min		- Max		Min		- Max	
								25%	50%	75%	100%	25%	50%	75%	100%	25%	50%	75%	100%	25%	50%	75%	100%
0.3 GPM #3	20	20	C	VC		F	F	2	4	6	8	2	3	5	6	1	2	4	5	1	2	3	4
	30	30	M	VC		F	F	3	5	8	10	2	4	6	8	2	3	5	6	1	3	4	5
	40	39	M	C		F	F	3	6	9	12	2	4	7	9	2	4	5	7	1	3	4	6
	50	49	F	C		F	F	3	7	10	13	2	5	7	10	2	4	6	8	2	3	5	7
	60	59	F	M		F	F	4	7	11	14	3	5	8	11	2	4	6	9	2	4	5	7
	70	69	F	M		F	F	4	8	12	15	3	6	9	12	2	5	7	9	2	4	6	8
0.4 GPM #4	20	19	C	VC	UC	F	F	3	5	8	11	2	4	6	8	2	3	5	7	1	3	4	5
	30	29	C	VC	UC	F	F	3	7	10	13	3	5	8	10	2	4	6	8	2	3	5	7
	40	39	M	C	XC	F	F	4	8	12	15	3	6	9	12	2	5	7	9	2	4	6	8
	50	49	M	C	XC	F	F	4	9	13	17	3	6	10	13	3	5	8	10	2	4	6	9
	60	58	F	M	XC	F	F	5	9	14	19	4	7	11	14	3	6	8	11	2	5	7	9
	70	68	F	M	XC	F	F	5	10	15	20	4	8	11	15	3	6	9	12	3	5	8	10
0.5 GPM #5	20	19	VC	XC	UC	F	M	3	7	10	13	3	5	8	10	2	4	6	8	2	3	5	7
	30	29	C	VC	UC	F	F	4	8	12	16	3	6	9	12	2	5	7	10	2	4	6	8
	40	38	C	C	XC	F	F	5	9	14	19	4	7	11	14	3	6	9	11	2	5	7	9
	50	48	M	C	XC	F	F	5	11	16	21	4	8	12	16	3	6	10	13	3	5	8	11
	60	58	M	C	XC	F	F	6	12	17	23	4	9	13	17	3	7	10	14	3	6	9	12
	70	67	F	M	XC	F	F	6	13	19	25	5	9	14	19	4	8	11	15	3	6	9	13
0.6 GPM #6	20	19	XC	XC	UC	F	M	4	8	12	16	3	6	9	12	2	5	7	9	2	4	6	8
	30	28	VC	VC	UC	F	M	5	10	15	19	4	7	11	15	3	6	9	12	2	5	7	10
	40	38	C	VC	XC	F	F	6	11	17	22	4	8	13	17	3	7	10	13	3	6	8	11
	50	47	C	C	XC	F	F	6	13	19	25	5	9	14	19	4	8	11	15	3	6	9	13
	60	56	M	C	XC	F	F	7	14	21	27	5	10	15	21	4	8	12	16	3	7	10	14
	70	66	M	M	XC	F	F	7	15	22	30	6	11	17	22	4	9	13	18	4	7	11	15
0.7 GPM #7	20	18	XC			F		5	9	14	18	3	7	10	14	3	5	8	11	2	5	7	9
	30	28	VC			F		6	11	17	22	4	8	12	17	3	7	10	13	3	6	8	11
	40	37	C			F		6	13	19	26	5	10	14	19	4	8	11	15	3	6	10	13
	50	46	C			F		7	14	21	29	5	11	16	21	4	9	13	17	4	7	11	14
	60	55	C			F		8	16	23	31	6	12	18	23	5	9	14	19	4	8	12	16
	70	65	M			F		8	17	25	34	6	13	19	25	5	10	15	20	4	8	13	17
0.8 GPM #8	20	18	XC		UC	M	M	5	10	15	20	4	8	11	15	3	6	9	12	3	5	8	10
	30	27	VC		UC	F	M	6	12	19	25	5	9	14	19	4	7	11	15	3	6	9	12
	40	36	C		XC	F	M	7	14	21	29	5	11	16	21	4	9	13	17	4	7	11	14
	50	45	C		XC	F	F	8	16	24	32	6	12	18	24	5	10	14	19	4	8	12	16
	60	54	C		XC	F	F	9	17	26	35	7	13	20	26	5	10	16	21	4	9	13	17
	70	63	M		XC	F	F	9	19	28	38	7	14	21	28	6	11	17	23	5	9	14	19
0.9 GPM #9	20	18	XC			M		6	11	17	22	4	8	12	17	3	7	10	13	3	6	8	11
	30	26	VC			F		7	14	20	27	5	10	15	20	4	8	12	16	3	7	10	14
	40	35	VC			F		8	16	23	31	6	12	18	23	5	9	14	19	4	8	12	16
	50	44	C			F		9	17	26	35	7	13	20	26	5	10	16	21	4	9	13	17
	60	53	C			F		10	19	29	38	7	14	22	29	6	11	17	23	5	10	14	19
	70	61	M			F		10	21	31	41	8	16	23	31	6	12	19	25	5	10	16	21
1.0 GPM #10	20	17	XC		UC	M	VC	6	12	18	24	4	9	13	18	4	7	11	14	3	6	9	12
	30	26	VC		UC	F	C	7	15	22	29	5	11	16	22	4	9	13	18	4	7	11	15
	40	34	VC		UC	F	M	8	17	25	34	6	13	19	25	5	10	15	20	4	8	13	17
	50	43	C		UC	F	M	9	19	28	38	7	14	21	28	6	11	17	23	5	9	14	19
	60	51	C		UC	F	M	10	21	31	41	8	16	23	31	6	12	19	25	5	10	16	21
	70	60	C		UC	F	M	11	22	33	45	8	17	25	33	7	13	20	27	6	11	17	22

Figure 1. PWM Nozzle Selection Chart from GreenLeaf Technologies for 20-in. Nozzle Spacing. From *Nozzles for PWM systems* by GreenLeaf Technologies, n.d. (https://greenleaftech.com/PWM_Brochurev2.pdf).

Target Parameters

Nozzle spacing = 20 in.

Target Application Rate = 10 GPA

Average Ground Speed = 10 mph (min. = 2.7 mph, max = 13.3 mph)

Desired droplet size = Medium

Steps to Use a PWM Nozzle Selection Chart

(reference the red boxes superimposed on the chart in Figure 2)

1. Find the target application rate on the chart in the top row and move down the rate column to find the ground speeds that are closest to the selected average speed (listed here in the yellow columns labeled 75% duty cycle), minimum, and maximum speeds (listed under 25% and 100% duty cycles, respectively). There will be usually two to three nozzle options that fit these criteria. In this case, for 10 GPA, it is 40 to 60 psi range for the #4 nozzle (red) and 30 to 40 psi for the #5 nozzle (brown).
2. Now moving left on the chart, check if any of the selected speeds satisfy the desired Medium droplet size requirement. This step will narrow down the nozzle size options to usually one or two that still fit the application requirements. For the example application, there are only two nozzles—BPDF #4 at 40 and 50 psi, and BP #4 at 60 psi—that meet the application requirements within the selected travel speeds.
3. From the available options, we can see that both the selected nozzles (BPDF and BP) would be good options for this application. However, according to the nozzle manufacturer, BPDF is an asymmetrical dual-fan nozzle and is recommended over BP (single-fan) for attaining medium spray quality and maximum coverage. Therefore, the best nozzle for applying 10 GPA with Medium droplets within the ground speed of 3 to 13 mph is a BPDF #4 nozzle at 40 to 50 psi.
4. Remember that depending upon the nozzle manufacturer and the available nozzle types, there can be two to three different nozzle options that fit the desired application requirements, so try to select the one that provides the most flexibility in terms of application.
5. Generally, most operators use the same nozzles for different pesticide applications, so it is recommended to run the same procedure again for other possible application scenarios—such as

higher rates (15–20 GPA) or faster speeds (12–15 mph)—to check if the same nozzles can be used for other intended applications or if operators should plan on purchasing another set of nozzles.

Tip Size	Gauge (PSI)	Nozzle (PSI)	BPDF	BP	SD	DF	TCP	7.5 GPA				10 GPA				12.5 GPA				15 GPA			
								Min		- Max		Min		- Max		Min		- Max		Min		- Max	
								25%	50%	75%	100%	25%	50%	75%	100%	25%	50%	75%	100%	25%	50%	75%	100%
0.3 GPM #3	20	20	C	VC		F	F	2	4	6	8	2	3	5	6	1	2	4	5	1	2	3	4
	30	30	M	VC		F	F	3	5	8	10	2	4	6	8	2	3	5	6	1	3	4	5
	40	39	M	C		F	F	3	6	9	12	2	4	7	9	2	4	5	7	1	3	4	6
	50	49	F	C		F	F	3	7	10	13	2	5	7	10	2	4	6	8	2	3	5	7
	60	59	F	M		F	F	4	7	11	14	3	5	8	11	2	4	6	9	2	4	5	7
	70	69	F	M		F	F	4	8	12	15	3	6	9	12	2	5	7	9	2	4	6	8
0.4 GPM #4	20	19	C	VC	UC	F	F	3	5	8	11	2	4	6	8	2	3	5	7	1	3	4	5
	30	29	C	VC	UC	F	F	3	7	10	13	3	5	8	10	2	4	6	8	2	3	5	7
	40	39	M	C	XC	F	F	4	8	12	15	3	6	9	12	2	5	7	9	2	4	6	8
	50	49	M	C	XC	F	F	4	9	13	17	3	6	10	13	3	5	8	10	2	4	6	9
	60	58	F	M	XC	F	F	5	9	14	19	4	7	11	14	3	6	8	11	2	5	7	9
	70	68	F	M	XC	F	F	5	10	15	20	4	8	11	15	3	6	9	12	3	5	8	10
0.5 GPM #5	20	19	VC	XC	UC	F	M	3	7	10	13	3	5	8	10	2	4	6	8	2	3	5	7
	30	29	C	VC	UC	F	F	4	8	12	16	3	6	9	12	2	5	7	10	2	4	6	8
	40	38	C	C	XC	F	F	5	9	14	19	4	7	11	14	3	6	9	11	2	5	7	9
	50	48	M	C	XC	F	F	5	11	16	21	4	8	12	16	3	6	10	13	3	5	8	11

Figure 2. Illustration of Nozzle Selection Using the GreenLeaf PWM Nozzle Selection Chart. The parameters for this application are: target rate = 10 GPA, ground speed range = 3–13 mph, and droplet size = Medium.
From *Nozzles for PWM systems* by GreenLeaf Technologies, n.d. (https://greenleaftech.com/PWM_Brochurev2.pdf).

Most nozzle or sprayer manufacturers have similar charts for sizing PWM nozzles, but the format for listing application rate and/or speed ranges can differ slightly. As an example, the TeeJet PWM nozzle selection chart, shown in Figure 3, provides the minimum and maximum travel speeds under each application rate instead of listing travel speeds at different duty cycles as in the GreenLeaf Technologies chart. However, despite the layout and formatting differences among different charts provided by nozzle manufacturers, the process for selecting the nozzle will be very similar to the steps outlined earlier.

Taking the same application example used above and using the TeeJet PWM nozzle selection chart (Figure 3), we will move down the 10-GPA column and see that there are two nozzles (TT and TTJ60, tip size 11004 at 50 psi) that meet both the target rate and droplet size requirements. While both nozzles are good options for this application, TTJ60 is a twin-fan nozzle and may be preferred over TT because of enhanced coverage and/or when spraying crops with more vertical canopies, such as cotton or wheat.

TIP SIZE	GAUGE PRESSURE (PSI)	30% MINIMUM DUTY CYCLE								SPEED RANGE (MPH)													
		TJ60	XR / XRC	TT	TTJ60	AITTJ60	TTI60	TTI	APTJ *	5 GPA		7.5 GPA		10 GPA		12 GPA		15 GPA		17.5 GPA		20 GPA	
										MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX
11001	20		F	C						1.2	4	0.8	3	0.6	2	0.5	1.7	0.4	1.4	0.4	1.2	0.3	1.0
	30		F	M						1.6	5	1.1	4	0.8	3	0.7	2	0.5	1.8	0.5	1.5	0.4	1.3
	40		F	M						1.8	6	1.2	4	0.9	3	0.7	2	0.6	2	0.5	1.7	0.4	1.5
	50		F	M						2	7	1.3	4	1.0	3	0.8	3	0.7	2	0.6	1.9	0.5	1.6
	60		VF	M						2	7	1.4	5	1.1	4	0.9	3	0.7	2	0.6	2	0.5	1.8
	70			F						2	8	1.5	5	1.2	4	1.0	3	0.8	3	0.7	2	0.6	2
	80			F						2	8	1.7	6	1.2	4	1.0	3	0.8	3	0.7	2	0.6	2
	90			F						3	9	1.8	6	1.3	4	1.1	4	0.9	3	0.8	3	0.7	2
110015	20		F	VC				UC	UC	2	7	1.3	4	1.0	3	0.8	3	0.7	2	0.6	1.9	0.5	1.6
	30		F	C				UC	UC	2	8	1.5	5	1.2	4	1.0	3	0.8	3	0.7	2	0.6	2
	40		F	M				XC	UC	3	9	1.8	6	1.3	4	1.1	4	0.9	3	0.8	3	0.7	2
	50		F	M				XC	UC	3	10	2	7	1.5	5	1.3	4	1.0	3	0.9	3	0.8	3
	60		F	M				XC	XC	3	11	2	7	1.6	5	1.3	4	1.1	4	0.9	3	0.8	3
	70			M				VC	XC	4	12	2	8	1.8	6	1.5	5	1.2	4	1.0	3	0.9	3
	80			F				VC	XC	4	12	2	8	1.9	6	1.6	5	1.2	4	1.1	4	0.9	3
	90			F				VC	XC	4	14	3	9	2	7	1.7	6	1.4	5	1.2	4	1.0	3
11002	20		M	VC	C	XC	UC	UC	UC	2	8	1.7	6	1.2	4	1.0	3	0.8	3	0.7	2	0.6	2
	30	F	F	C	C	VC	XC	UC	UC	3	10	2	7	1.5	5	1.3	4	1.0	3	0.9	3	0.8	3
	40	F	F	M	M	VC	XC	XC	UC	4	12	2	8	1.8	6	1.5	5	1.2	4	1.0	3	0.9	3
	50	F	F	M	M	C	VC	XC	UC	4	13	3	9	2	7	1.6	5	1.3	4	1.1	4	1.0	3
	60	F	F	M	M	C	VC	XC	UC	4	14	3	10	2	7	1.8	6	1.4	5	1.2	4	1.1	4
	70			M	M	C	VC	VC	XC	5	15	3	10	2	8	2	6	1.5	5	1.3	4	1.2	4
	80			F	M	C	C	VC	XC	5	17	3	11	2	8	2	7	1.7	6	1.4	5	1.2	4
	90			F	M	M	C	VC	XC	5	18	4	12	3	9	2	7	1.8	6	1.5	5	1.3	4
11025	20		M	VC	VC	XC	UC	UC	UC	3	11	2	7	1.6	5	1.3	4	1.1	4	0.9	3	0.8	3
	30		M	C	C	VC	XC	UC	UC	4	13	3	9	2	7	1.6	5	1.3	4	1.1	4	1.0	3
	40		F	M	M	VC	XC	XC	UC	4	15	3	10	2	7	1.9	6	1.5	5	1.3	4	1.1	4
	50		F	M	M	VC	VC	XC	UC	5	17	3	11	2	8	2	7	1.7	6	1.4	5	1.2	4
	60		F	M	M	C	VC	XC	UC	6	18	4	12	3	9	2	8	1.8	6	1.6	5	1.4	5
	70			M	M	C	VC	VC	XC	6	20	4	13	3	10	2	8	2	7	1.7	6	1.5	5
	80			F	M	C	C	VC	XC	6	21	4	14	3	10	3	9	2	7	1.8	6	1.6	5
	90			F	M	C	C	VC	XC	7	23	5	15	3	11	3	9	2	8	2	6	1.7	6
11003	20		M	VC				UC	UC	4	12	2	8	1.9	6	1.6	5	1.2	4	1.1	4	0.9	3
	30		M	C	C	XC	XC	UC	UC	5	15	3	10	2	8	2	6	1.5	5	1.3	4	1.2	4
	40	F	F	M	C	VC	XC	XC	UC	5	18	4	12	3	9	2	7	1.8	6	1.5	5	1.3	4
	50	F	F	M	M	VC	XC	XC	UC	6	20	4	13	3	10	2	8	2	7	1.7	6	1.5	5
	60	F	F	M	M	C	XC	XC	UC	6	21	4	14	3	11	3	9	2	7	1.8	6	1.6	5
	70			M	M	C	VC	VC	XC	7	23	5	15	3	12	3	10	2	8	2	7	1.7	6
	80			F	M	C	VC	VC	XC	7	24	5	16	4	12	3	10	2	8	2	7	1.8	6
	90			F	M	C	VC	VC	XC	8	26	5	17	4	13	3	11	3	9	2	7	2	7
11004	20		M	VC				UC	UC	5	16	3	11	2	8	2	7	1.6	5	1.4	5	1.2	4
	30		M	C	C	XC	UC	UC	UC	6	20	4	13	3	10	3	8	2	7	1.7	6	1.5	5
	40	F	M	M	C	VC	XC	XC	UC	7	23	5	15	3	12	3	10	2	8	2	7	1.7	6
	50	F	F	M	M	VC	XC	XC	UC	8	26	5	17	4	13	3	11	3	9	2	7	2	7
	60	F	F	M	M	VC	XC	XC	UC	9	29	6	19	4	14	4	12	3	10	2	8	2	7
	70			M	M	C	VC	VC	XC	9	31	6	21	5	15	4	13	3	10	3	9	2	8
	80			M	M	C	VC	VC	XC	10	33	7	22	5	16	4	14	3	11	3	9	2	8
	90			F	M	C	VC	VC	XC	10	34	7	23	5	17	4	14	3	11	3	10	3	9
11005	20		M	VC				UC	UC	6	20	4	13	3	10	3	8	2	7	1.7	6	1.5	5
	30		M	VC	C	XC	UC	UC	UC	7	24	5	16	4	12	3	10	2	8	2	7	1.8	6
	40	M	M	C	C	XC	XC	UC	UC	9	29	6	19	4	14	4	12	3	10	2	8	2	7
	50	M	F	M	M	VC	XC	XC	UC	10	32	6	21	5	16	4	13	3	11	3	9	2	8
	60	M	F	M	M	VC	XC	XC	UC	10	34	7	23	5	17	4	14	3	11	3	10	3	9
	70			M	M	VC	XC	XC	UC	11	37	7	25	6	19	5	16	4	12	3	11	3	9
	80			M	M	C	VC	VC	XC	12	40	8	27	6	20	5	17	4	13	3	12	3	10
	90			F	M	C	VC	VC	XC	13	43	9	29	6	21	5	18	4	14	4	12	3	11

Figure 3. TeeJet Technologies PWM Nozzle Selection Chart for 20-in. Nozzle Spacing.
From *PWM spray tip selection*, by TeeJet Technologies, 2020 (https://www.teejet.com/-/media/dam/agricultural/usa/sales-material/product-market-bulletin/li-tj371m-r1-pwm-turf-hi-res.pdf).

Other Useful Tools for PWM Nozzle Selection

In addition to the nozzle selection tabulation charts provided by nozzle manufacturers, there are some other useful tools—both web- and mobile-based applications—available online either through the nozzle manufacturers or other third-party technology companies for selecting the right nozzles for both conventional and PWM sprayers. One of the main benefits of using these online tools, specifically for PWM nozzles, is that it eliminates the need for operators to do any calculations for minimum and maximum travel speeds, and automatically takes that into consideration based on the user-entered application parameters. In most cases, these interactive applications also provide additional information (e.g., duty cycle and droplet size at different pressures) than is typically presented on the nozzle selection charts.

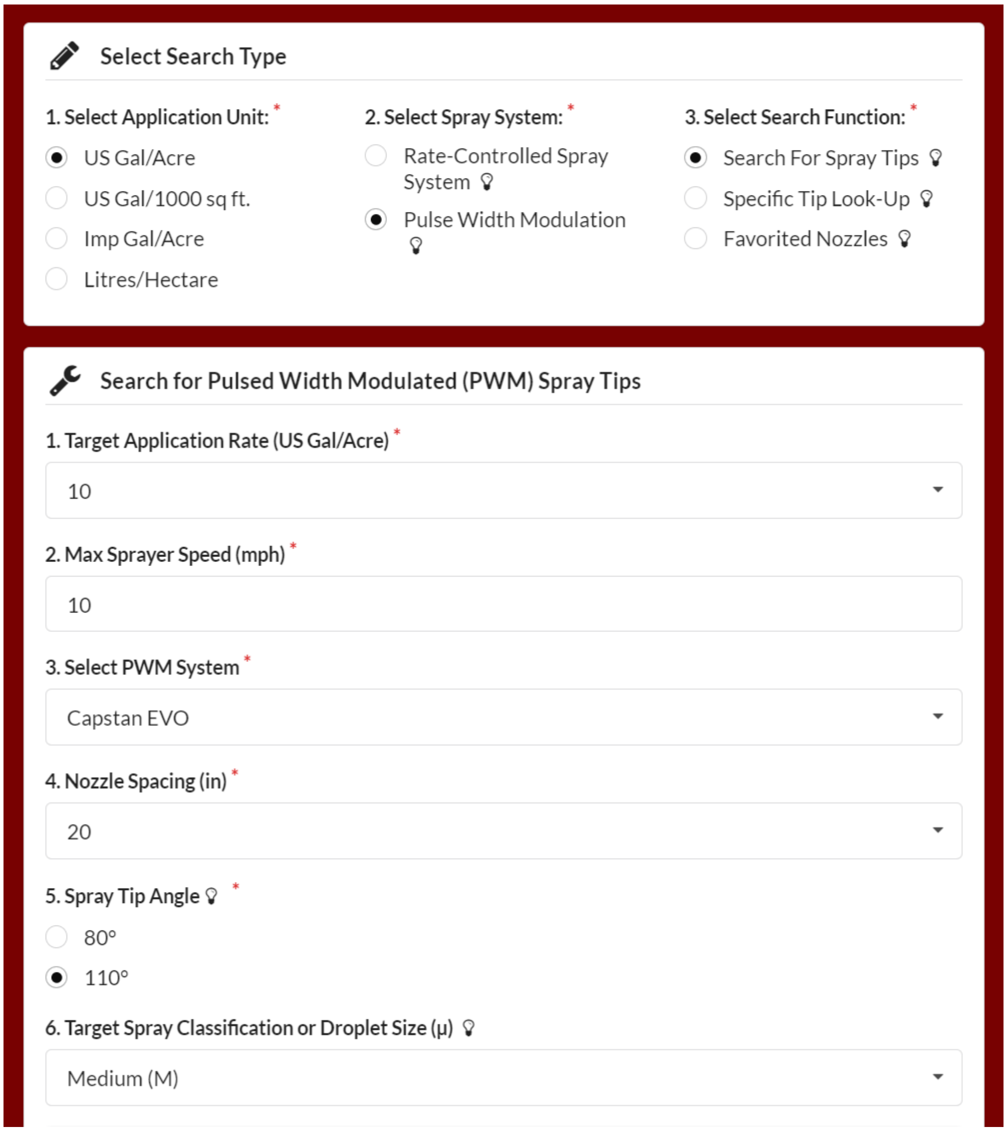

Figure 4. Example User Interface: Wilger's Tip Wizard Tool for PWM Nozzle Selection. From *Tip wizard tool*, by Wilger Inc., 2022 (https://www.wilger.net/ tip-wizard/).

"Tip Wizard" is one of the tools offered by Wilger Inc. for selecting a nozzle for different PWM systems currently available in the market. The user selects the preferred units and the PWM option for the spray system (Figure 4), then inputs the required parameters such as target application rate, ground speed, nozzle spacing, and droplet size for the intended application. The user can also select the specific PWM system available on the sprayer from a list of options.

Once all the required parameters are entered, the results provide a few different nozzle options based on the selected application parameters as shown in Figure 5. Each nozzle option can be further expanded to see detailed information on the speed range, duty cycle, and droplet size corresponding to different pressures. This information is then used to select the operating pressure for the intended application as well as the minimum and maximum travel speeds within which the PWM system can maintain the target application rate and droplet size.

− Combo-Jet® ER110-05
Part No: 40281-05 Color: Brown
Screen No: 50 Mesh (#40250-00)

Pressure (psi)	Speed Range (mph)	DC (%) @ 10 mph	Class	VMD (μ)	<141 (%)	<600 (%)
20	2.5-10.0	100	M	253μ	17	95
25	2.8-11.2	89	M	241μ	19	95
30	3.1-12.2	82	M	231μ	21	95
35	3.3-13.2	76	M	224μ	23	95
40	3.5-14.1	71	M	217μ	25	95
45	3.7-15.0	67	F	211μ	26	95
50	3.9-15.8	63	F	207μ	27	95
55	4.1-16.6	60	F	202μ	28	95
60	4.3-17.3	58	F	198μ	29	95
65	4.5-18.0	56	F	195μ	30	95

+ Combo-Jet® ER110-06
Part No: 40281-06 Color: Grey
Screen No: Not Required

+ Combo-Jet® ER110-08
Part No: 40281-08 Color: White
Screen No: Not Required

Figure 5. Details Shown in a Sample Nozzle Selection Interface.
From *Tip wizard tool*, by Wilger Inc., 2022 (https://www.wilger.net/ tip-wizard/).

For the application example discussed earlier (10 GPA rate, 10 mph average speed, and Medium droplets), the Tip Wizard suggested using a Wilger Combo-Jet ER, 05 nozzle. It also shows the target duty cycle at the average speed of 10 mph along with different speed ranges corresponding to each pressure. For the selected application, operating the Combo-Jet ER, 05 nozzle at 35 psi and 76% duty cycle at 10 mph will maintain the desired application rate and droplet size within the travel speeds of

3.3 to 13.2 mph.

Wilger also offers their online tool Tip Wizard as a mobile application that can be installed on smart devices (Android and iOS) and can be used in a similar way as the web-based application for selecting a PWM nozzle. Figure 6 shows the mobile app interface, the various screens for user input, and the nozzle results based on the target application parameters.

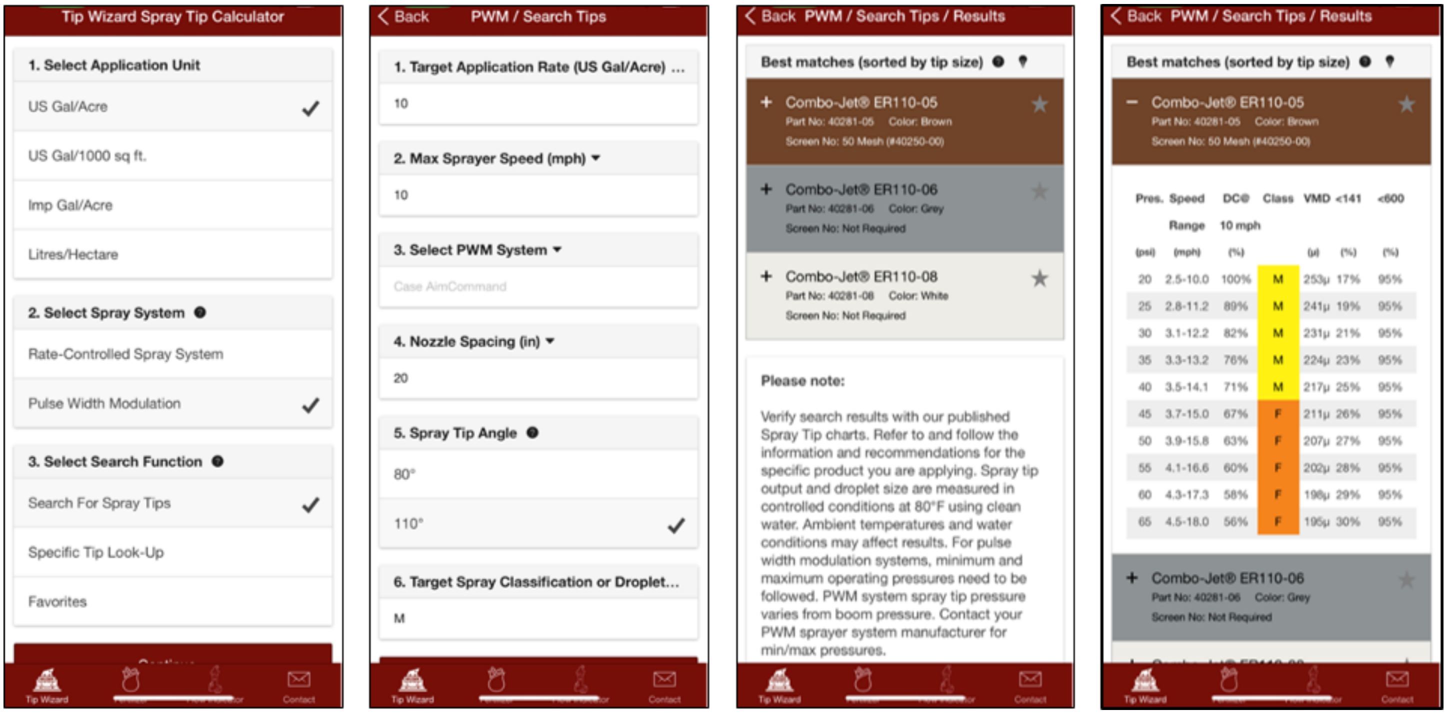

Figure 6. Wilger's Tip Wizard Mobile App Interface.

When searching for these online PWM nozzle selection tools, it is important to note that while numerous web and mobile applications are available to select nozzles for conventional sprayers without PWM, very few have the functionality to recommend nozzles specific to PWM sprayers. Therefore, the user/operator should check first with their preferred nozzle or sprayer manufacturer to see if their web or mobile application is suitable for selecting nozzles for PWM sprayers. If this option is unavailable, then the nozzle selection/tabulation charts discussed at the beginning of this publication are still the best tool.

As the interest and adoption of PWM sprayers increase among growers, the availability of these online tools from more nozzle and sprayer manufacturers is also expected to increase.

Additional Considerations for PWM Nozzle Selection

There are some additional considerations that operators should follow when selecting nozzles for

PWM sprayers to minimize issues and obtain the best system performance during application.

1. **Overlap:** One of the concerns with PWM systems is the risk of skips during application caused by the blended pulse (i.e., alternate nozzles coming on and off). Thus, always choose wider-angle spray nozzles, such as 110° or greater, to ensure there is enough overlap for adequate coverage and to maintain spray quality.
2. **Compatibility:** Always check the list of approved nozzles from nozzle manufacturers for use with PWM sprayers. While new advancements have been made regarding the compatibility of air-induction (AI) nozzles for PWM systems, avoid using AI nozzles in general with PWM systems because the air induction and the pulsing action of solenoids do not work together properly and can lead to deterioration in spray quality.
3. **Ideal Pressure Range:** While lower pressures (20–30 psi) are commonly used with coarser-droplet nozzles on traditional sprayers, avoid selecting nozzles that will require the PWM system to operate at pressures lower than 30 psi and higher than 60 psi. In general, the performance of PWM systems is best when operated between 40 to 50 psi.
4. **Minimum Pressure:** For PWM sprayers, the system or boom pressure is different from the pressure at the nozzle tip because of a pressure drop caused by the solenoids turning on and off. This pressure drop can be considerably greater for larger-orifice nozzles (e.g., 6 psi for a 110-08 nozzle at 30 psi boom pressure) and at higher pressures. While the PWM systems adjust for this pressure loss to ensure correct nozzle output, operators should account for this pressure loss by operating the PWM system above the nozzle manufacturer's recommended pressure minimums.
5. **Ideal Duty Cycle** Ideally, a PWM sprayer should be operating between 60% and 80% duty cycle for the selected nozzle, but lower duty cycles—such as below 50% and above 90%—also are expected momentarily as large variations in ground speed occur during application. Consider going up or down a nozzle size if the system is continuously operating outside the preferred duty cycle range for the majority of the time during application. While some manufacturers specify the minimum duty cycle to be as low as 30%, most university research suggests that the optimal performance from most PWM systems is attained when operated above 50% duty cycle.

Resources for PWM Nozzle Selection

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Wilger Inc. (2022). *Tip wizard tool*. https://www.wilger.net/ tip-wizard/

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Status and Revision History
In Review on Jul 31, 2024
Published on Oct 03, 2024

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