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Spray Application Technology

Selecting Spray Nozzles with Drift-Reducing Technology

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What nozzle should I use?

That is a complex question. And the answer is becoming more complex, especially if tank mixing contact and systemic herbicides or multiple pesticide types (herbicides, fungicides, insecticides). Some of the many nozzles on the market include technologies to reduce particle drift. Would these nozzles be right for you?

Whether a low-drift nozzle fits your program depends on your spraying needs and operation. Nozzles that produce smaller droplets supply better coverage and the pesticide is retained better on the leaf surface, especially when the target plant is smaller. However, small droplets are more susceptible to particle drift.

Drift-reducing nozzles typically produce larger droplets that are less prone to drift, but droplets that are too large may bounce or run off the target and be lost to the soil surface.

Is a drift-reducing nozzle right for you? Let's dive into the considerations.

Consider Your Needs

Consider your priorities before making nozzle choices. Nozzles are relatively inexpensive, but they can be the most critical part of your spray system.

- What droplet sizes, aka spray quality, do your nozzles need to produce?
- What water volumes do your nozzles need to produce?
- At what ground speeds do you plan to run your sprayer?
- Are you planning to spray a dicamba formulation or 2,4-D formulation that is subject to Environmental Protection Agency (EPA) requirements for over-the-top applications to soybean?
- How many sets of nozzles are you willing to buy?

Among pesticide types commonly used in postemergence foliar applications, systemic herbicides generally require the lowest application volumes and allow for the largest droplet sizes (coarse to very coarse spray quality).

Contact herbicides require comparatively higher application volumes, along with medium to coarse spray quality.

Insecticides and fungicides generally require fine to medium spray quality and similar or higher application volumes as contact herbicides.

Over-the-top dicamba applications to crops with the dicamba-tolerant trait require nozzle configurations that supply extremely coarse or ultra coarse spray quality.

No one nozzle will be ideal for all of the pesticide application needs outlined above. Consider the application protocols necessary to maximize the efficacy of your crop protection products, then choose a set of nozzles accordingly.

Be a Responsible Steward

Every pesticide applicator bears responsibility for ensuring a successful and on-target pesticide application. Some situations call for heightened concern about pesticide drift.

- Is particle drift likely to be highly damaging? Are you applying nonselective or highly active herbicides?
- Are you spraying near sensitive crops or sensitive areas, such as shelterbelts, neighboring fields or rural homes?
- Is the pesticide a restricted use pesticide due to its potential for off-target movement or significant environmental impacts?

If you answered “yes” to any of these questions, you should be especially concerned about pesticide drift. Using a drift-reducing nozzle would be a sound management practice.

However, be aware that drift-reducing nozzles only reduce particle drift; they do not eliminate all drift. Spraying when a susceptible crop is downwind still may cause damage. Also, drift-reducing nozzles do not reduce volatility, aka vapor drift.

Follow the Pesticide Label

Whatever nozzle you choose, the pesticide label is the law and must always be followed. You will be breaking the law if you choose to spray in violation of any application restrictions on a pesticide label. For example:

- Does the label specify nozzle selection and spray volume?
- Does the label restrict applications under certain environmental conditions, such as wind speed, relative humidity and air temperature?

The EPA evaluates drift potential as a routine part of its pesticide risk assessments. As part of assessing new pesticides and reevaluating older pesticides for registration and labeling, EPA evaluates the potential for each pesticide to drift and strengthens labeling as needed. New pesticide labels have more detailed information about the factors that significantly affect spray drift, such as spray droplet size categories (aka spray quality), spray release heights, minimum and maximum wind speeds, and buffer zones, if necessary.

Pesticide registrants are encouraged to include verified drift reduction technologies as part of their product label use directions, considering factors such as application ground speed, spray pressure, nozzle selection, pesticide characteristics, pesticide tank-mix partners, adjuvants and wind speed.

The collective efforts of pesticide registrants and EPA, when put into practice by pesticide applicators, should ensure that more of the applied pesticide reaches the crop, resulting in improved overall pest control and reduced loss of pesticide from the target.

Example: Dicamba and 2,4-D Herbicides for Soybeans

One example of nozzle selection for pesticide label compliance can be found with the dicamba and 2,4-D products approved for over-the-top applications to soybeans with the proper resistance trait.

The pesticide labels for these products specify that they may only be applied using the nozzles and operating pressures listed on the product websites. As of this writing, just three of the 15 nozzle models featured in this publication’s illustrative nozzle set may be used for applying dicamba: the Air Induction TeeJet, Turbo TeeJet Induction and Hypro Ultra Lo-Drift. In contrast, seven of these nozzle models may be used to apply Enlist One or Enlist Duo. They are the Billericay Air Bubble Jet, Greenleaf AirMix, Greenleaf TurboDrop XL, Hypro Ultra Lo-Drift, Air Induction TeeJet, AIXR TeeJet and Turbo TeeJet. Always reference the latest pesticide labels for information on allowable spray nozzles.

The approved nozzle tip and operating pressure combinations will generate an extremely coarse or ultra coarse spray quality (Table 1).

Spray Nozzle Droplet Size Classification

Before diving into the specifics of drift-reducing nozzles, it is important to understand the classification system for spray nozzle droplet size.

The standard of measurement for spray droplets is the micron, equivalent to 1/1000 millimeter or approximately 1/25,000 inch. In comparison, one human hair is about 100 microns in diameter.

All hydraulic spray nozzles (those that use hydraulic pressure to atomize droplets) will create a spectrum of droplet sizes. Due to the heterogeneity of droplet sizes they produce, it is impractical to report the specific droplet sizes produced by spray nozzles. Rather, nozzles are categorized into spray quality categories based on summary statistics of their droplet size distributions.

The American Society of Agricultural and Biological Engineers (ASABE) standard S572.3 outlines a droplet size classification system that is a helpful aid in selecting spray nozzles. The standard specifies a set of reference nozzles and their reference operating pressure and flow rate. The droplet size spectra produced by these reference nozzles under reference conditions, as summarized by three statistics of a spray volume distribution — $D_{v0.1}$, $D_{v0.5}$, and $D_{v0.9}$ — define the thresholds between eight spray quality classifications ranging from extremely fine to ultra coarse (Table 1).

The $D_{v0.5}$, also known as the volume median diameter (VMD), could be considered the midpoint droplet size of the spray volume distribution. Half of the spray volume is contained in droplets smaller than the VMD and half of the spray volume is in droplets larger than the VMD.

The $D_{v0.1}$ characterizes the smallest droplets of the spray volume distribution; 10% of the spray volume is in droplets smaller than the $D_{v0.1}$. These small droplets are a major contributor to the drift-susceptible fines. To minimize drift, the $D_{v0.1}$ should be 150 microns or greater.

The $D_{v0.9}$ characterizes the largest droplets of the spray volume distribution; 90% of the spray volume is in droplets smaller than the $D_{v0.9}$, therefore 10% of the spray volume is in droplets larger than the $D_{v0.9}$. A large $D_{v0.9}$ indicates that excessively large spray drops would be produced and may result in poor leaf coverage or droplets lost to nontarget areas such as the soil.

Example Applications of ASABE S572.3

Let us consider two nozzles as examples of the ASABE S572.3 classification system (Figure 1). The ISO F 110 02 and ISO Injet 02 are flat-fan type nozzles manufactured by Hardi. When operated under identical conditions, 44 pounds per square inch (psi) operating pressure and 0.21

Table 1. Approximate $D_{v0.1}$, $D_{v0.5}$ and $D_{v0.9}$ droplet size limits for spray quality categories defined in ASABE S572.3, and comparative descriptions of droplets ranging in size from fog to thunderstorm rain.

ASABE S572.3 Spray Quality Category	ASABE S572.3 Approximate Droplet Size Limits[a] (microns)		
	$D_{v0.1}$ (smallest 10%)	$D_{v0.5}$ (midpoint)	$D_{v0.9}$ (largest 10%)
UC (Ultra Coarse)	230 or greater	665 or greater	1155 or greater
XC (Extremely Coarse)	170 or greater	485 or greater	880 or greater
VC (Very Coarse)	140 or greater	350 or greater	665 or greater
C (Coarse)	130 or greater	270 or greater	525 or greater
M (Medium)	105 or greater	195 or greater	360 or greater
F (Fine)	75 or greater	150 or greater	225 or greater
VF (Very Fine)	75 or greater	100 or greater	155 or greater
XF (Extremely Fine)	up to 74	up to 99	up to 154

Understanding Micron Size[b]		
Degree of Atomization	Droplet Size (microns)	Relative Size Related to Common Objects
Fog	up to 20	point of a needle (25 microns)
Fine Mist	20-100	human hair (100 microns)
Fine Drizzle	100-250	sewing thread (150 microns)
Light Rain	250-1000	staple (420 microns)
Thunderstorm Rain	1000-4000	pencil lead (2000 microns)

[a] Estimated by Proulx from example reference graph in ASABE S572.3
[b] Source: Whitford et al., 2014

gallons per minute (gpm), they produced the droplet size distributions displayed in the lower panels of Figure 1. Corresponding illustrations of the droplet size distributions using common household objects are in the upper panels of Figure 1.

With $D_{v0.1}$, $D_{v0.5}$ and $D_{v0.9}$ values of 113, 214 and 344 microns, respectively, the ISO F 110 02 nozzle at 44 psi produces a fine (F) spray quality. Approximately 60% its spray volume consists of droplets with sizes from 100 to

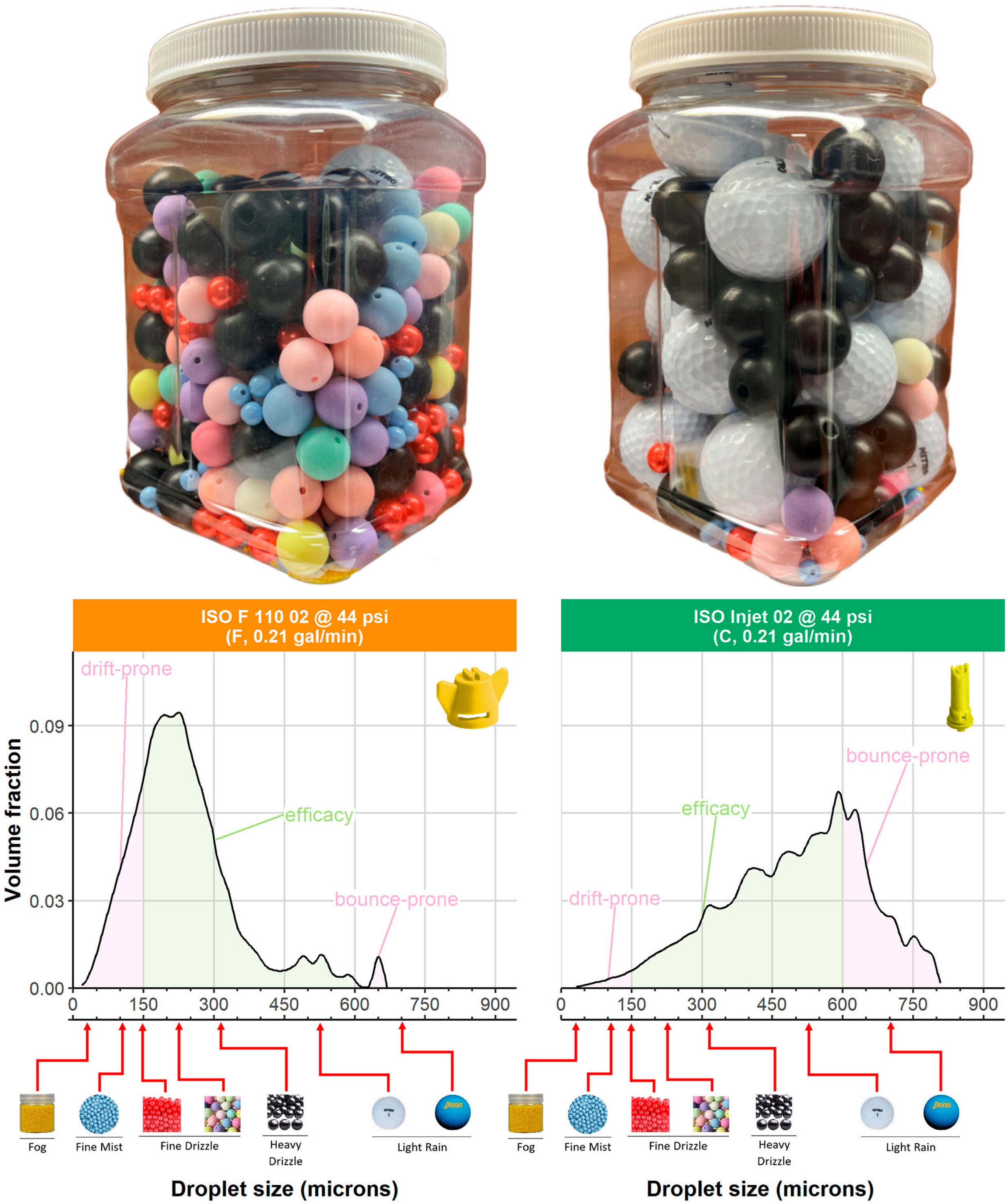

Figure 1. Distributions of spray volume fraction by droplet size, expressed graphically and illustrated by jars filled with common household objects. Spray quality classifications of fine (F) and coarse (C) are according to ASABE S572.3, for sprays produced by a Hardi ISO F 110 02 spray nozzle at 44 psi and a Hardi ISO Injet 02 spray nozzle at 44 psi. Graphs created by Proulx using the experimental data of Nuyttens et al. (2007). Jars created by Proulx.

250 microns, similar in size to a fine mist or fine drizzle, and approximately 20% of its spray volume consists of drift-prone droplets sized 150 microns or smaller. In contrast, less than 5% of its spray volume is found in droplets with sizes of 500 microns or larger.

In contrast, the ISO Injet 02 nozzle has air induction drift-reducing technology (see the Drift-Reducing Nozzle Technologies section). With $D_{v0.1}$, $D_{v0.5}$ and $D_{v0.9}$ values of 282, 507 and 645 microns, respectively, this nozzle produces a coarse (C) spray quality when operated at 44 psi. Only 6% of its spray volume is found in droplets of 100 to 250 microns, with less than 2% of its volume consisting of drift-prone droplets sized 150 microns or smaller. However, this nozzle produces approximately 50% of its volume in droplets with sizes of 500 microns or larger, including approximately 25% of its volume in droplets sized 600 microns or larger. Droplets of this size could be considered prone to bouncing off target plants, especially if produced by a standard hydraulic nozzle, but air induction nozzles seem to more effectively deposit these large droplets on the target. This is most likely due to the reduced exit velocity of droplets from an air induction nozzle, which results from pressure drop at the exit orifice.

ASABE S572.3 vs. S572.1

ASABE S572.3 is the latest update to the ASABE droplet size classification standard and was published in February 2020. As of this writing, most nozzle manufacturer catalogs display spray quality classifications according to ASABE S572.1, which was published in March 2009.

Compared to S572.1, S572.3 decreased the reference operating pressure and flow rate for the nozzles defining the C/VC, VC/XC and XC/UC spray quality thresholds. This effectively increased the droplet sizes of the $D_{v0.1}$, $D_{v0.5}$ and $D_{v0.9}$ that define these thresholds, meaning that nozzle spray qualities rating as VC, XC, or UC according to S572.1 could shift into the next finer category under S572.3 (C, VC and XC, respectively). S572.3 also flipped the colors used to define coarse and very coarse spray qualities to make ASABE S572.3 fully equivalent to the International Organization for Standardization (ISO) 25358:2018 droplet size classification standard.

The changes implemented in S572.3 should not greatly impact nozzle selection decisions for pesticide applications. However, keep in mind that spray quality reported across manufacturer catalogs may be defined by different standards and that spray quality reported by a nozzle catalog may be defined by a different standard than spray quality reported in other reference materials, such as a pesticide label.

Drift-Reducing Nozzle Technologies

Figure 1 illustrates that a nozzle with air induction technology (ISO Injet 02) produces far fewer drift-prone droplets than a similar nozzle without air induction (ISO F 110 02). The rest of this publication addresses the two most common drift-reducing nozzle technologies: the pre-orifice turbulence chamber and air induction (aka Venturi) designs. The extended range flat fan nozzle is an example of the standard hydraulic spray nozzle design and provides a basis of comparison to the drift-reducing nozzle technologies.

According to data from TeeJet Technologies, a leading nozzle manufacturer, a pre-orifice flat fan nozzle can reduce drift-prone droplets by 50% or more compared to an extended-range flat fan nozzle. An air induction flat fan nozzle can reduce drift-prone droplets by 80% or more. Figures 2 and 3 illustrate the differences in drift between a standard hydraulic flat fan and a drift-reducing air induction nozzle.

Figure 2. Standard hydraulic flat-fan nozzles at 40 psi. Photo credit: Wolf, 1999.

Figure 3. Air induction nozzles at 70 psi. Photo credit: Wolf, 1999.

Drift-reducing nozzles are designed to produce larger spray droplets with fewer drift-prone fines. These nozzles are excellent at reducing drift but will not eliminate all drift. You still must use caution when susceptible crops are downwind.

Nozzle designs that incorporate air induction technology generally cost more than standard hydraulic flat fan nozzles, but the cost may be worth the extra expense if they prevent drift injury. A drift problem may cost thousands of dollars, so a few extra dollars for a set of drift-reducing nozzles should be considered a worthwhile investment.

Standard Hydraulic

Extended-range flat fan nozzles were historically considered the standard nozzle for many pesticide applications in the northern Plains. Variations of this standard hydraulic design, where liquid is drawn in through an inlet and atomized through an exit orifice (Figure 4), are still available from several manufacturers.

The design is available in a wide range of flow rates and fan angles to fit many application needs. These nozzles produce a uniform spray pattern when patterns are overlapped 30% to 50% and when operated at 15 to 60 psi.

Spray quality is fine to medium for small nozzles (0.4 gpm and lesser). Larger nozzles (0.5 to 0.8 gpm) will produce medium to very coarse spray quality. At any nozzle size, higher pressures (above 30 to 40 psi) will produce a greater proportion of drift-prone droplets.

At any given flow rate and pressure, an extended-range flat fan nozzle with an 80-degree discharge angle will produce slightly larger droplets than a comparable 110-degree nozzle.

Pre-orifice Turbulence Chamber

Pre-orifice nozzles feature an internal turbulence chamber between the liquid inlet and the exit orifice (Figure 4). The turbulence chamber absorbs energy from the incoming liquid stream, reducing exit pressure from the nozzle. This creates larger droplets and a more uniform spray distribution, resulting in fewer drift-prone droplets.

Air Induction (Venturi)

All air induction nozzles, also known as air inclusion or Venturi nozzles, share the same basic design feature: two orifices, one to meter liquid flow and the other larger orifice to form the pattern. Between these two orifices is a Venturi or jet, which is used to draw air into the nozzle body (Figure 4).

Within the nozzle body, liquid pressure decreases and air mixes with the liquid. The resulting spray consists of large, air-filled droplets and very few drift-prone droplets.

Air induction nozzles differ from conventional low-pressure spray nozzles by producing coarse droplets with few fines. Most manufacturers of air induction nozzles recommend optimum pressures of 40 to 50 psi and higher for best performance. These operating pressures are generally greater than those needed for standard hydraulic nozzles.

Getting the maximum benefit from air induction nozzles requires proper operation and careful choice of the right nozzle for your needs. You need to be aware of differences in pressure operating ranges, ease of cleaning and the ability to fit into existing nozzle caps.

Most air induction nozzles are designed to be disassembled for cleaning, but disassembly may require needle-nosed pliers, a small screwdriver or a piece of fine wire. Cleaning air induction nozzles in the field is difficult because they usually have some very small pieces that could be easily lost.

All brands of air induction nozzles can be installed on any standard spray boom. Some nozzles may require a different nozzle cap, so be aware of this when making a purchase.

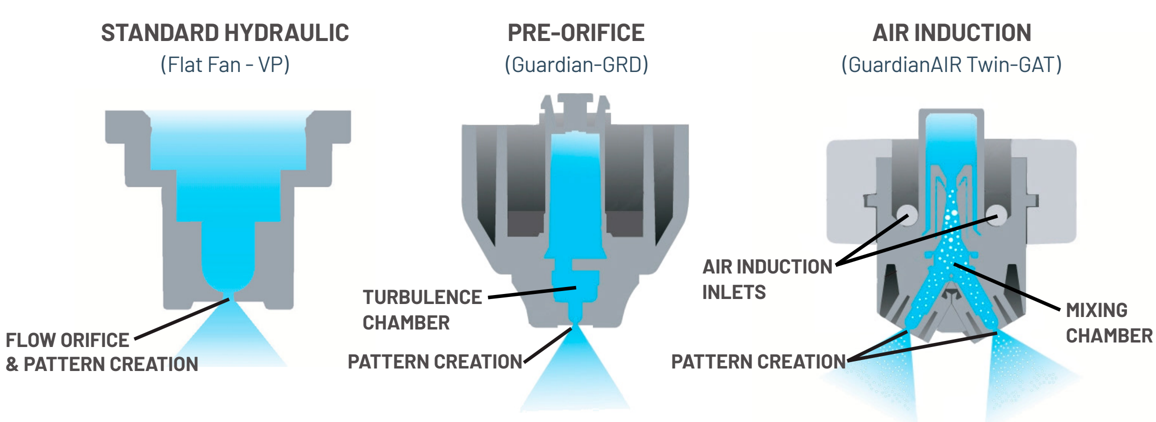

Figure 4. Examples of standard hydraulic, pre-orifice, and air induction nozzle technologies. Adapted from Pentair, 2018.

Proper Spray Quality + Proper Water Volume = Proper Coverage

Drift-reducing nozzles help to ensure that a greater proportion of spray droplets travel to their intended target. It is equally important to provide a sufficient number of droplets to cover the spray target and that these droplets exist in a form that will impact and be retained on the target. Therefore, in addition to drift potential, applicators must consider target species and coverage requirements when selecting nozzles and resultant spray quality.

The labels for fungicides, insecticides, and contact herbicides often recommend the use of a medium to coarse spray quality, while labels for soil-applied insecticides and systemic herbicides often recommend coarse spray quality, which is more resistant to drift. Some herbicides recommend the use of extremely coarse or ultra coarse spray quality for even better drift control.

Some weeds are more difficult targets than others, particularly small weeds under a dense canopy or difficult-to-wet weeds, such as lambsquarters and grasses. Sprays with finer droplet sizes may help supply effective coverage, but finer drops do not penetrate thick plant canopies as well as larger drops.

To make an effective pesticide application, water volume must be considered in tandem with spray quality. Application water volume is an especially important consideration when using drift-reducing nozzles, as they generate larger droplets than standard hydraulic nozzles. At a given water volume, doubling droplet size reduces droplet number eightfold (Figure 5). Therefore, the larger droplets produced by drift-reducing nozzles may need to be paired with greater water volumes to ensure adequate spray coverage.

This matrix illustrates the relationship between droplet size, water volume and coverage (Figure 6). The degree of coverage represented in the middle panel, with coarse

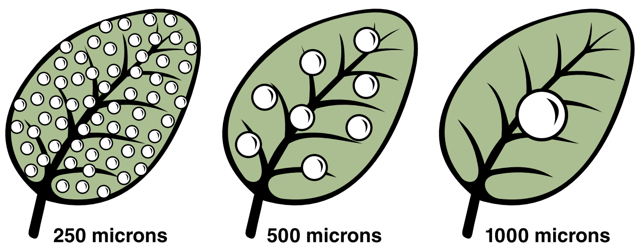

Figure 5. Relationship between droplet size and droplet number. Sixty-four droplets with diameters of 250 microns each would reduce to eight droplets at 500 microns diameter and one droplet at 1,000 microns diameter.
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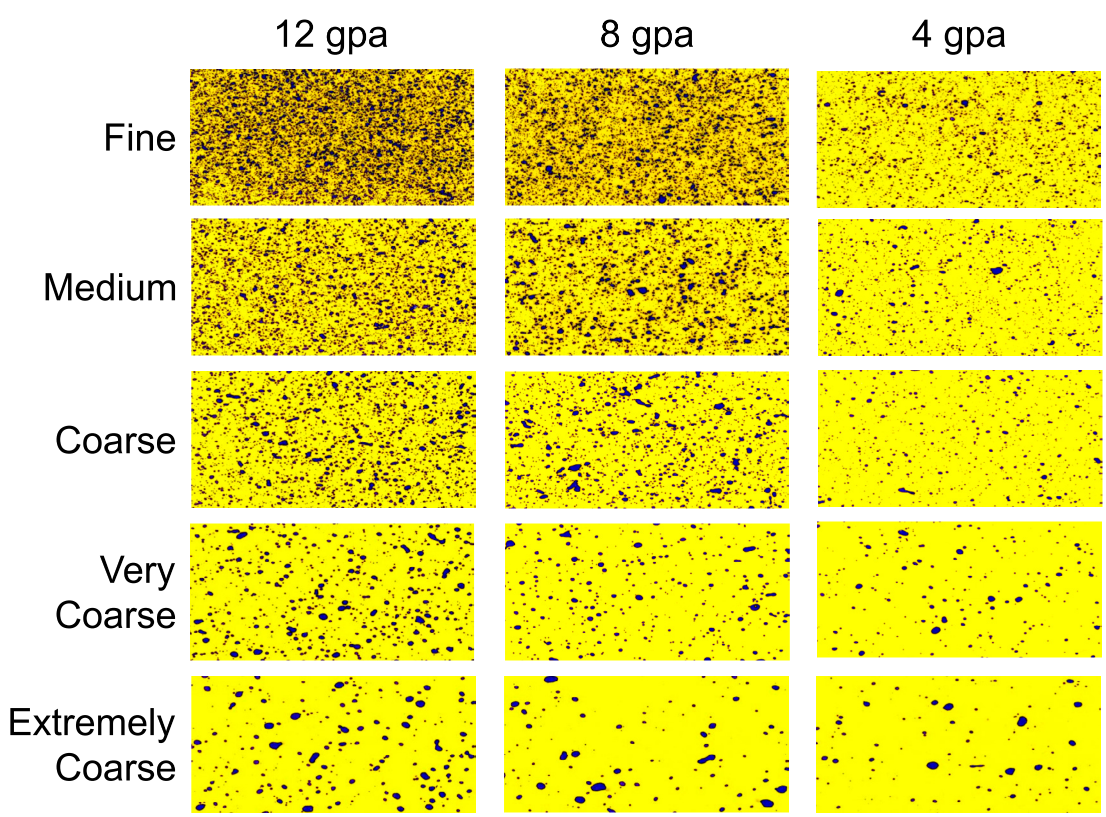

Figure 6. Matrix of water-sensitive papers sprayed under controlled conditions at three water volumes (4, 8, 12 gallons per acre [gpa]) and five spray qualities (F, M, C, VC, XC), illustrating the relationship between water volume, spray quality and coverage.
Photo credit: Wolf, 2015.

spray quality and 8 gallons per acre (gpa) water volume, is a good starting point for pesticide applications where coarse spray quality would be desirable. As droplets get larger, at very coarse and extremely coarse spray qualities, there are fewer of them, and coverage may be compromised. To compensate for this, use higher water volumes.

Note that as droplets become finer, there are more of them, and coverage is increased. However, these cards were sprayed under controlled conditions. Therefore, the degree of observed coverage is truly hypothetical, especially under a fine spray quality, as many of these drift-prone droplets would drift off target.

Illustrative Nozzle Set

These 15 nozzles (Table 2) provide examples of nozzles with low-drift technologies contrasted against an extended flat fan nozzle with standard hydraulic technology.

Spray nozzle manufacturers provide selection guides, available on the company website or in a nozzle catalog, that can help select a nozzle design for a specific application. For the illustrative nozzle set, Table 3 provides similar nozzle selection guidelines for various categories of herbicides. Once a nozzle design has been chosen, an applicator can refer to the detailed spray nozzle table to select the proper tip size, operating pressure and sprayer travel speed to produce the desired spray quality and application water volume.

Figure 7 presents images on water-sensitive paper of the spray deposit produced by the illustrative nozzle set. The images were produced from nozzles operated at their standard or optimum pressure and configured to apply approximately 8 gpa. Spot cards were sprayed lying on a horizontal surface and do not indicate coverage on an inclined or vertical surface.

Due to the unavailability of ASABE S572.3 spray quality classifications in most nozzle manufacturer catalogs, spray quality classifications in Table 2, Table 3 and Figure 7 are according to ASABE S572.1.

Table 2. Characteristics of the 15 nozzles included in this publication's illustrative nozzle set.

			Pressure (psi)		ASABE S572.1 Categories[c]							
Manufacturer	Spray Nozzle	Angle	Rated[a]	Mid 50%[b]	XF	VF	F	M	C	VC	XC	UC
standard hydraulic												
TeeJet	XR TeeJet	80,110	15-60	30-50			•	•				
pre-orifice turbulence chamber												
Pentair	Hypro Guardian	120	20-115	40-90				•	•	•		
TeeJet	Turbo TeeJet	110	15-90	30-70				•	•	•		
air induction												
Greenleaf	AirMix	110	15[d]-90	30-70			•	•	•			
Pentair	Hypro GuardianAIR	110	20[d]-115	40-90				•	•			
Greenleaf	TurboDrop XL	110	20[d]-120	50-100			•	•	•	•	•	
Lechler	IDK (Air-injector Flat Spray Compact)	90,120	15[d]-90	30-70				•	•	•		
Pentair	Hypro Ultra Lo-Drift	120	20[d]-115	40-90				•	•	•	•	
Billericay	Air Bubble Jet	100	30-75	40-60					•	•	•	
TeeJet	AIXR TeeJet (Air-induced XR Flat Fan)	110	15[d]-90	30-70					•	•	•	
Pentair	Hypro AVI (Air Injected Anti-Drift)	80	30-100	50-80					•	•	•	
Hardi	Injet	110	40-120	60-100						•		
TeeJet	Air Induction TeeJet	80,110	30-100	50-80						•	•	
Delavan	Raindrop Ultra	110	30-80	40-70						•	•	
TeeJet	Turbo TeeJet Induction	110	15[d]-100	40-80							•	•

[a] Manufacturer-rated pressure range.
[b] Middle 50% of the manufacturer-rated pressure range; spray nozzles perform best when operated near the middle of their pressure range.
[c] Summarizes spray quality from 02-08 nozzle tip sizes (0.2 to 0.8 gpm) operating within the middle 50% of their rated pressure range. These combinations would be generally capable of applying 8-20 gpa water volume at 8-15 mph. Classifications according to ASABE S572.1.
[d] Spray pattern breakdown may occur when air induction nozzles are operated at less than 30 psi.

Table 3. Nozzle selection guidelines for weed control.

Herbicide type	Spray Nozzle				
	XR TeeJet 	Hypro Guardian 	Turbo TeeJet 	Greenleaf AirMix 	Hypro GuardianAIR 
Soil residual	Good[a]	Good[a]	Good[a]	Very Good	Very Good
Postemergence contact	Very Good[a]	Very Good[a]	Very Good[a]	Good[b]	Good[b]
Postemergence systemic	Very Good[a]	Very Good[a]	Very Good[a]	Very Good	Very Good
Spray qualities[c]	F M	M C VC	M C VC	F M C	M C

Herbicide type	Spray Nozzle				
	Greenleaf TurboDrop XL 	Lechler IDK 	Hypro Ultra Lo-Drift 	Billericay Air Bubble Jet 	AIXR TeeJet 
Soil residual	Very Good	Very Good	Very Good	Very Good	Very Good
Post emergence contact	Good[b]	Good[b]	Good[b]	Not recommended	Not recommended
Post emergence systemic	Very Good	Very Good	Very Good	Very Good	Very Good
Spray qualities[c]	F M C VC XC	M C VC	M C VC XC	C VC XC	C VC XC

Herbicide type	Spray Nozzle				
	Hypro AVI 	Hardi Injet 	Air Induction TeeJet 	Delavan Raindrop Ultra 	Turbo TeeJet Induction 
Soil residual	Very Good	Very Good	Very Good	Very Good	Very Good
Post emergence contact	Not recommended	Not recommended	Not recommended	Not recommended	Not recommended
Post emergence systemic	Very Good	Very Good	Very Good	Very Good	Very Good
Spray qualities[c]	C VC XC	VC	VC XC	VC XC	XC UC

[a] Smaller nozzle sizes at high operating pressures will generate an excessive number of drift-prone droplets.
[b] Use operating pressures that generate Medium to Coarse spray quality.
[c] Spray qualities from 02-08 nozzle tip sizes (0.2 to 0.8 GPM) operating within the middle 50% of their rated pressure range. These combinations would be generally capable of applying 8-20 gpa water volume at 8-15 mph. Classifications according to ASABE S572.1.

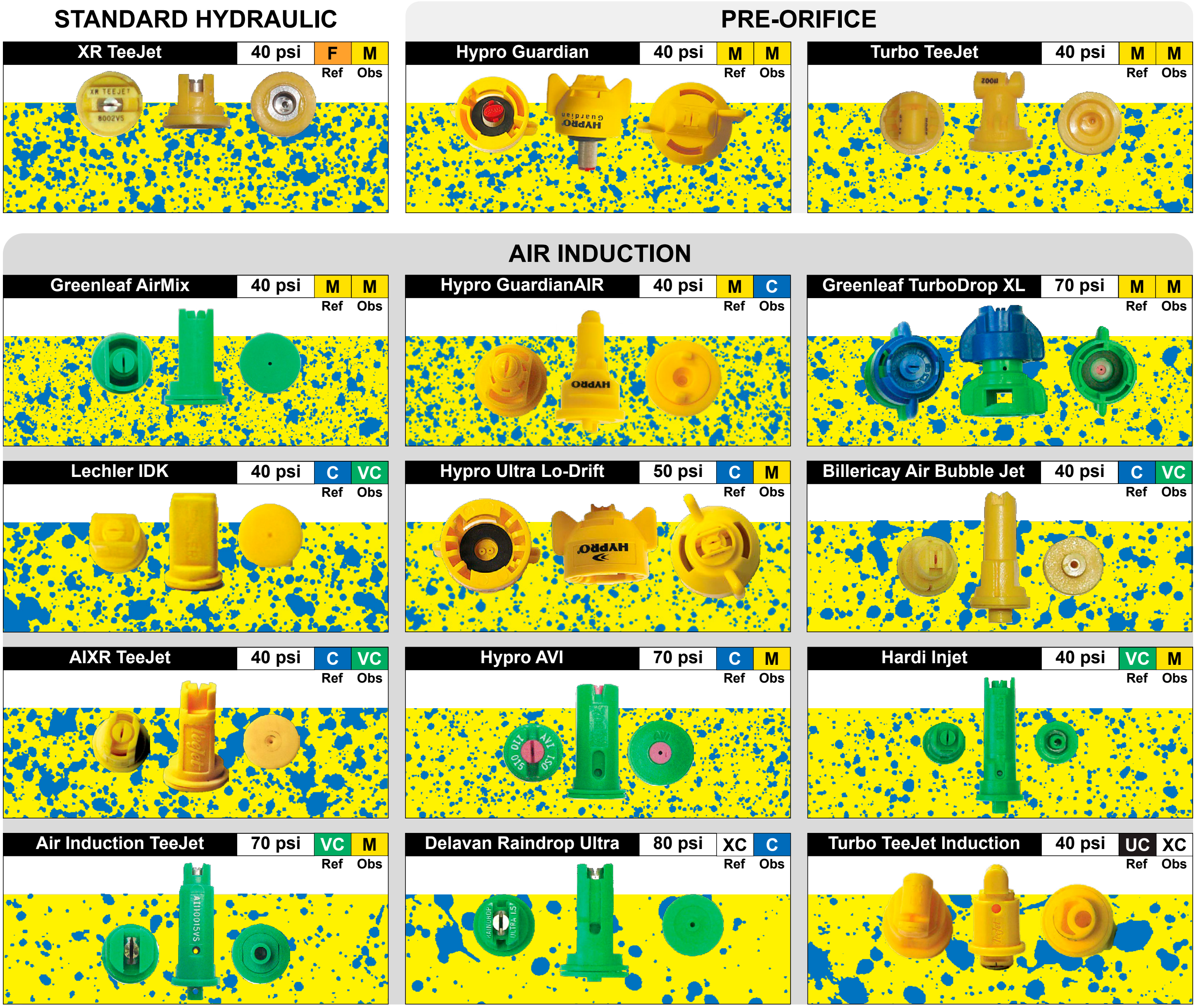

Figure 7. Spray droplet deposits on water-sensitive paper for each of the 15 nozzles in the representative nozzle set at the indicated operating pressure and 8 gpa water volume. Also included are the reference spray qualities (Ref) taken from manufacturer nozzle catalogs and the observed spray qualities (Obs) according to $D_{v0.1}$, $D_{v0.5}$ and $D_{v0.9}$ values returned by WRK DropletScan™ spray droplet analysis software. Spray qualities are according to ASABE S572.1. NDSU graphic.

Pre-orifice Examples

The Hypro Guardian and Turbo TeeJet are examples of nozzles featuring the pre-orifice turbulence chamber drift-reducing technology.

Both nozzles produce a wide, uniform spray pattern with a slight inclination, which allows the spray to be directed slightly forward or backward. These nozzles can also be operated over wide pressure ranges (Table 2). This makes them well-suited for use with automatic rate controllers that use pressure to adjust the flow rate in response to a change in travel speed.

When operated at pressures near the middle of their manufacturer-authorized ranges, commonly used nozzle tip sizes will produce medium to very coarse spray quality (Table 3). The spray qualities produced by these nozzles are most suitable for postemergence applications of contact herbicides, where adequate herbicide efficacy requires greater spray coverage compared to systemic herbicides. Pre-orifice nozzles such as these are generally better suited for contact herbicide applications than are air induction nozzles, as pre-orifice nozzles tend to produce relatively finer spray qualities than many of the air induction nozzles (Table 2, Figure 7).

Air Induction Examples

Among the air induction nozzles in the example set, the Greenleaf AirMix, Hypro GuardianAIR, Greenleaf TurboDrop XL, Lechler IDK and Hypro Ultra Lo-Drift nozzles are collectively capable of producing fine or medium spray qualities, in addition to the coarser spray qualities more typically associated with air induction nozzles (Tables 2 and 3). These nozzles are well suited for the application of soil residual and postemergence systemic herbicides and are also acceptable for contact herbicide applications (Table 3).

All other air induction nozzles are not rated to produce medium or finer spray qualities when using typical nozzle tip sizes operated at pressures near the middle of their manufacturer-authorized ranges (Tables 2 and 3). The Billericay Air Bubble Jet, AIXR TeeJet and Hypro AVI nozzles produce coarse to extremely coarse spray qualities, while the Hardi Injet, Air Induction TeeJet, Delavan Raindrop Ultra and Turbo TeeJet Induction nozzles produce only very coarse or coarser spray qualities. While these nozzles are well suited for applying soil residual and postemergence systemic herbicides, they are not recommended for applying contact herbicides (Table 3).

Figure 7 illustrates the variation in spray quality produced by the example air induction nozzles when holding water volume constant at 8 gpa. Note that the observed spray quality does not always match the reference spray quality taken from manufacturer catalogs, as the method used to measure spray quality (analysis of water-sensitive paper) is much less precise than the method manufacturers use to measure nozzle spray quality (measurement with a laser-based instrument).

The example air induction nozzles also differ in their design features (Table 4). Several nozzles offer an optional ceramic pre-orifice or exit orifice, which provides high wear resistance compared to polymer. Most nozzles feature a two-piece design where the pre-orifice is removable without requiring any special tools, which eases cleaning, but some nozzles require a needle-nosed pliers to remove the pre-orifice. Due to their wider nozzle body, certain nozzles require a specialized nozzle cap for attachment to the sprayer boom. However, most nozzles fit a standard Spraying Systems Quick TeeJet nozzle cap or feature an integrated cap with an identical fitment.

Table 4. Design features of air induction nozzles.

		Construction[a]			Removable	
Manufacturer	Spray Nozzle	Body	Pre-orifice	Exit orifice	pre-orifice	Nozzle cap[b]
Greenleaf	AirMix	P	P	P	yes	ST
Pentair	Hypro GuardianAIR	P	P	P	no	ST or IN
Greenleaf	TurboDrop XL	P	P or C	P	yes	IN
Lechler	IDK (Air-injector Flat Spray Compact)	P	P or C	P or C	yes	ST
Pentair	Hypro Ultra Lo-Drift	P	P	P	yes	ST or IN
Billericay	Air Bubble Jet	P	P	P	yes	ST
TeeJet	AIXR TeeJet (Air-induced XR Flat Fan)	P	P or C	P or C	yes	ST
Pentair	Hypro AVI (Air Injected Anti-Drift)	P	C	C	yes	ST or IN
Hardi	Injet	P	P or C	P or C	yes[c]	SP
TeeJet	Air Induction TeeJet	P	P	SS	yes[c]	SP
Delavan	Raindrop Ultra	P	P	SS	yes	ST
TeeJet	Turbo TeeJet Induction	P	P	P	yes	SP

[a] C = ceramic, P = polymer, SS = stainless steel
[b] ST = standard, SP = specialized, IN = integrated
[c] requires a needle-nosed pliers to remove the metering orifice and Venturi insert.

Nozzle Manufacturers

Several principal spray nozzle manufacturers supply local equipment dealers. Each manufacturer distributes nozzle catalogs that can be obtained from your local dealer or ordered from the following websites (accessed: July 2024):

ABJ Agri Products
www.abjagri.com

Albuz
https://albuz-spray.com/en

ARAG (a division of Nordson Corporation)
www.nordson.com/en/divisions/precision-agriculture

Billericay Farm Services Ltd.
www.bfs.uk.com

Delavan AgSpray Products
https://delavanagspray.com

Greenleaf Technologies
https://greenleaftech.com

Hardi North America
https://hardi.com/en-us

Lechler Inc.
www.lechlerusa.com/en/markets/agriculture

Pentair (Hypro)
www.pentair.com/en-us/products/business-industry/agricultural-products/spray-nozzles.html

Spraying Systems Co. – TeeJet Technologies
www.teejet.com

VariTarget
https://spraytarget.com

Wilger Industries Ltd.
www.wilger.net

CP Nozzles
https://cpnozzles.com/

Important Considerations with Air Induction Nozzles

Pressure Requirements

Whether featuring a pre-orifice or air induction design, drift-reducing nozzle tips result in an internal pressure drop within the tip body and reduced operating pressure at the exit orifice. Due to this design, drift-reducing nozzle tips require greater operating pressures than standard hydraulic nozzles.

Check the operating pressure of your sprayer and the ability of your pump to supply the higher pressures necessary for these drift-reducing nozzles. If your spray system has trouble exceeding 60 psi, consider replacing the pump or using a nozzle that produces a desirable droplet size at lower pressures.

Pressure loss across the length of the boom may cause variation in the discharge from nozzles so check operating pressure along the boom to ensure it is uniform and at the nozzle manufacturer's minimum pressure. When using an automatic flow regulator, watch boom pressure and sprayer output closely when changing speeds. Poor spray patterns are often the primary reason for performance complaints.

Spray Pattern and Coverage

While operating pressure and nozzle design are the primary determinants of droplet size, the primary determinants of spray pattern and coverage are spray fan angle, nozzle spacing on the boom and boom height. Most fan-pattern nozzle tips feature spray fan angles from 80 to 120 degrees (Table 2). North American sprayers typically feature 20-inch nozzle spacing, and nozzle catalogs typically specify the proper boom height for their nozzles at this spacing. The optimum boom heights are usually configured to supply a recommended 100% spray overlap for fan-pattern nozzles, meaning that the edges of a nozzle's spray should align directly underneath the adjacent nozzles on the boom.

A proper spray angle is critical to achieving the recommended spray overlap and coverage. Therefore, understand that the spray angle does not remain constant with changes in operating pressure, as a decrease in pressure causes the spray angle to narrow. This is of particular concern with air induction nozzles.

Although many air induction nozzles are sold as 110-degree fan angles, their spray pattern sometimes is closer to 80 degrees and quickly becomes narrower at lower pressures.

This is because the exit orifice has a greater flow rate than the metering orifice, causing a significant pressure drop at the exit orifice, which narrows patterns. Even at a gauge pressure of 80 psi, the exit tip pressure may be only 20 to 40 psi. Watch patterns carefully and set your boom at the height needed to achieve proper overlap.

Even though manufacturers may rate air induction nozzles to operate over a wide pressure range, this does not mean that the spray angle remains constant. Aim to operate your nozzles near the middle of their rated pressure range, and be aware that spray pattern breakdown may occur when air induction nozzles are operated at pressures less than 30 psi. Lower pressures are of greater concern than higher pressures in terms of maintaining proper spray patterns.

Pulse Width Modulation (PWM) Sprayers

In a flow-based control system, which is traditional for agricultural sprayers, a sprayer controller adjusts operating pressure in response to variations in ground speed. This maintains a constant application rate. In contrast, pulse width modulation (PWM) sprayers provide independent control over nozzle pressure and flow rate. This is done by using a rapidly pulsing solenoid within each nozzle body to vary the amount of time spray is flowing to the nozzle.

Operating pressure does not change with travel speed on a PWM sprayer. Drift-reduction benefits come from using larger orifice nozzles to produce larger droplets at lower pressures while varying the application rate by varying the duty cycle of the solenoid.

Nozzles with pre-orifice drift-reducing technology are compatible with PWM sprayers. Air induction nozzles have traditionally been considered incompatible with PWM sprayers, as these designs can leak during the brief off-cycle. This causes an internal pressure drop within the nozzle, which must be replenished during the next on-cycle, which then affects pattern development and droplet atomization.

However, nozzle manufacturers recently have begun to publicize certain air induction nozzles as compatible with PWM sprayers. Proceed with caution and seek documentation of this compatibility before using air induction nozzles on a PWM sprayer.

Nozzle Wear, Plugging and Cleaning

Most air induction nozzles feature polymer (i.e., plastic) construction. Polymer has very good wear characteristics and can sometimes outlast stainless steel. However, polymer is prone to deformation if cleaned with hard objects such as fine wire or a knife tip. Use only a soft-bristled brush, such as a nozzle-cleaning brush or a toothbrush, to clean polymer tips.

Nozzles occasionally plug, even with clean water and screens. However, an air induction nozzle should present fewer plugging problems than standard hydraulic nozzles because the metering orifice is round, allowing larger particles to pass through. Also, the exit orifice typically has about twice the flow rate of the metering orifice, further reducing the likelihood of plugging.

If the exit orifice of an air induction nozzle plugs, the nozzle must be taken apart for cleaning. Air induction nozzles sometimes are difficult to disassemble, especially in the field, and nozzle parts can be easily lost. Your best option may be to carry extra nozzles and disassemble and clean the plugged ones at the shop, where you have access to compressed air and water.

Adjuvants

Some adjuvants are marketed to improve spray deposition on intended targets and reduce spray drift. Some viscosity-modifying, drift-reducing adjuvants should not be used with air induction tips because the adjuvant may interfere with proper spray atomization and droplet formation.

Always read the pesticide and adjuvant labels for restrictions before use and check your spray pattern after adding any adjuvant.

The Bottom Line

Pre-orifice and air induction nozzle technologies have been used successfully by many applicators under a wide range of conditions. These nozzle technologies have an excellent capability for reducing drift while maintaining good efficacy, although air induction nozzles generally provide greater drift-reduction capability than pre-orifice nozzles. These nozzles can be used improperly, however. Follow these fundamentals of effective pesticide application.

Configure nozzles to provide the proper spray quality for your needs. Medium to coarse spray quality is generally best for insecticides, fungicides and contact herbicides, and when spraying weed species whose leaf characteristics make it difficult to achieve thorough spray coverage, such as lambsquarters, grasses or other narrow-leaved weeds. Coarse to very coarse spray quality generally works well for systemic herbicides and when spraying most broadleaf weeds. Extremely coarse and ultra course spray qualities are required for dicamba and 2,4-D formulations labeled for over-the-top application to soybean.

Don't consider spray quality independently from water volume since they are in relationship to each other. Increasing droplet size without concurrently increasing water volume reduces droplet number, which decreases coverage (Figures 5 and 6). Adequate coverage is essential when applying insecticides, fungicides and contact herbicides, and when spraying seedling weeds or weed species with leaf surfaces that repel or shed water.

Select the nozzle tip size and operating pressure that will supply the proper spray quality and water volume for your application needs. Nozzle tips generally perform best when operated near the middle of their rated pressure range. Do not operate air induction nozzles at less than 30 psi. If you cannot operate air induction nozzles near the middle of their rated pressure range, operate them toward the top of their rated pressure range rather than the bottom.

Although they generally provide coarser spray qualities than standard hydraulic or pre-orifice nozzles, the spray qualities produced by air induction nozzles are not uniformly coarse across all manufacturers' models (Table 2 and Figure 7). You may be able to find an air induction nozzle that produces medium to coarse spray qualities at the proper water volume for your needs.

Finally, always remember that the label is the law. If the label states a maximum wind speed for spraying, it must be followed, even when using drift-reducing nozzles.

Nozzles are the most important part of your sprayer. Using a spray nozzle best suited for the job at hand is a worthwhile investment.

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