SPRAYER NOZZLE SELECTION FOR PESTICIDE PERFORMANCE AND DRIFT REDUCTION

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Avoiding excessive spray drift is a key objective for applicators. With increasing acreage planted to herbicide-resistant crops and a shift to more postemergence spraying, the potential for off-target plant damage has increased in recent years. Off-site damage is often readily apparent in adjacent farmland and rural acreages. As increased emphasis is placed on drift-reduction, nozzle manufacturers have responded with new nozzle types designed to lower drift potential and accommodate new application technologies. Precision agriculture and site-specific farming have added additional demands for nozzles than can accommodate a wider pressure operating range.

It is impossible to completely eliminate drift. With any application some material will escape the intended target. The goal in pesticide application is to minimize the amount of off-target movement and reduce or eliminate injury to the surrounding environment. Off-target pesticide movement has an economic impact through injury to sensitive vegetation, reduction in control at the target site, and potential legal ramifications. As the number of organic production acres continues to grow in Iowa, pesticide drift is an even greater threat. A single drift event can cancel an operator's organic certification resulting in the loss of a high-value crop for 3 or more years. A greater concern is when an off-target pesticide becomes an environmental pollutant by affecting sensitive vegetation, causing health concerns for humans and wildlife, and polluting surface water supplies.

Pesticide drift occurs in two forms: particle drift and vapor drift. Vapor drift occurs when an applied pesticide volatilizes, or changes to a gaseous form, and moves off target. This occurs after the application and is not greatly affected by application variables such as nozzle size or volume. Particle drift is the physical movement of small droplets at the time of application. Particle drift is directly influenced by nozzle selection, boom height, pressure and weather conditions. This information will focus primarily on particle drift.

Droplet size and air movement

To understand particle drift and the many factors involved in reduction of drift, it is important to understand how spray droplets are measured and how size affects movement under various conditions. Droplet size is measured in microns (? m). One micron is 1 millionth of a meter, or approximately 1/25,000 of an inch. Table 1 lists the measurement of common items in microns to give a relationship to droplet size. Nozzles produce a wide range of droplet sizes. The term volume median diameter (Dv.5) is used to provide a basis to compare different nozzles. Volume median diameter is an indication of the mid-point droplet size produced by the nozzle. One-half of the total output volume is contained in droplets larger than the volume median diameter, and one-half of the volume is in droplets smaller than the volume median diameter. This shouldn't be considered an "average" droplet size, but a measure of the range of droplets size produced by the nozzle.

Table 1. Diameter of common items in microns (? m).

Measurement	Item
2000 ? m	#2 pencil lead
850 ? m	paper clip
300 ? m	toothbrush bristle
100 ? m	human hair
1 ? m	1/250,000 inch

Different types of applications require various droplet sizes. Insecticide and fungicides require smaller droplets to adequately cover smaller targets. Comparatively, common weedy broadleaves and grasses provide a much larger surface for spray droplets to deposit. However, the type of herbicide applied influences the effectiveness of different droplet sizes. Contact herbicides need greater target coverage to provide adequate control. Systemic herbicides, those that move within the plant, need less contact with the plant surface to provide control. After considerable research, it is generally accepted that nozzles producing droplets in the range of 100-400 microns will not greatly affect the performance of postemergence herbicides unless rates are extremely low or high or other uncommon conditions (Wolf, 1996.) Table 2 provides a comparison of droplet size and target coverage.

Table 2. Effect of spray droplet diameter on target coverage.

Droplet diameter, ? m	Type of droplet	Droplets/in^2 with 10 gal/a application
20	wet fog	1,440,000
50		92,200
10	mist	11,500
150		3,420
200	light rain	1,440
400		180

As droplet diameter decreases, so does mass. Smaller diameter droplets have greater surface area compared to larger droplets. With less mass and greater surface area, small droplets have more friction with surrounding air and therefore will fall much slower than larger droplets. Droplets are also affected by ambient air temperature and relative humidity. As temperature increases and relative humidity decreases, the droplet will evaporate more rapidly. As evaporation takes place, the diameter of the droplet decreases, resulting in a spray particle than takes longer to fall and is more susceptible to drift (table 3). Extremely small droplets, less than 50 microns, will evaporate very rapidly leaving only residual pesticide. Droplet sizes not subject to potential drift depends on wind speed and weather conditions, but generally are above 150 microns (Bode, 1984).

While wind is one of the greatest factors in drift management, still or calm conditions with no air movement also present challenges. Inversions are created when a layer of warm air is located between cooler air at the surface and farther up in the atmosphere. This is common in the early morning hours after a clear night. During inversion conditions, there is little vertical mixing and air currents close to the surface can move great distances with little turbulence. High concentrations of small droplets can become trapped in these currents, move great distances and come in contact with other vegetation close to the surface.

Table 3. Effects of spray droplet size on drift.

Droplet diameter, ? m	Terminal velocity, ft/sec	Deceleration distance, in.	Time to evaporate, sec	Final drop diameter, ? m	Drift distance in 1 ft. fall with 1 mph wind
20	0.04	<1	0.3	7	37 ft
50	0.25	3	1.8	17	6 ft
100	0.91	9	7	33	1.6 ft
150	1.7	16	16	50	10 in.
200	2.4	25	29	67	7 in.

Assumed: 90?F, 36% RH, 3.75% pesticide solution

Nozzle technology

The demand for spray nozzles that reduce drift has resulted in significant changes in nozzle design and the variety of nozzles available. Added to this is the demand for a nozzle that can operate under a wider pressure range to accommodate variable rate controllers. The challenge is to develop nozzles that can operate throughout the pressure range while maintaining a uniform droplet size with a minimum of small, drift-prone droplets.

One way to reduce drift is to use lower operating pressures. However, conventional flat-fan nozzles are designed to operate between 30 and 60 psi. To address this issue, many manufacturers developed nozzles that could operate through an extended pressure range. These new nozzles can operate as low as 15 psi without degrading the spray pattern and significantly reducing fine droplets.

For many years, Delavan, Inc. has marketed Raindrop? nozzle tips that produce large droplet sizes relatively independent of operating pressure. A cap limits the release of small droplets and pressure is reduced internally within the nozzle. These tips have been popular for soil-applied herbicides. More recently manufacturers have developed nozzles that use a pre-orifice to reduce pressure within the nozzle. Such nozzle tips are often called drift-reduction flat fan nozzles and are commonly used to obtain larger droplets at a given operating pressure. Examples would be the Drift Guard (DG) nozzles by Spraying Systems Co. and the Lo-Drift? nozzles by Lurmark.

Recent designs in nozzles have added the use of a turbulence chamber to further absorb energy within the tip and increase droplet size. Examples include the Turbo Teejet? by Spraying Systems Co., a small, flat fan tip, and the Turbo Floodjet? in a flooding tip design. Both produce larger droplet sizes than similar nozzles operated at a specific pressure without the turbulence chamber. Because these tips maintain their pattern over a wide pressure range, 15 to 90 psi, they are an excellent choice to use with a variable-rate spray controller.

Most recently designers have further increased droplet size by inducing air into the liquid stream inside the nozzle body. After spray flows through a metering pre-orifice inside the nozzle body, an inlet port introduces air into the liquid by venturi action. The droplets containing entrained air are generally larger than those produced by similar size nozzles using only a pre-orifice or turbulence chamber. The AI nozzles by Spraying Systems Co. and the TurboDrop? from Greenleaf Technologies are examples of tips utilizing this technology. These tips operate at a wide pressure range and higher pressures than other nozzles, from 30 to 135 psi. The amount of air entrained within the spray droplet is also dependent upon the composition of the spray solution. Research is ongoing to determine the effectiveness of this new design with various solutions.

When selecting nozzles, the actual size distribution of droplets produced must be considered to make adjustments for coverage and drift potential. In addition to the volume median diameter of the droplets produced, it is also important to consider the percentage of the spray volume that is considered “driftable.” This information for various spray nozzles is presented in table 4.

Table 4. Droplet size comparison of various spray nozzles. (Data provided by Spraying Systems Co. 1996)

Nozzle type (all nozzles are Spraying Systems)	40 psi @ 0.2 gpm	40 psi @ 0.5 gpm	60 psi @ 0.5 gpm	% spray volume < 200 ? m (0.5 gpm @ 40 psi)
Flat-fan 80°	270	370	300	11
XR Flat-fan 80°	270	370	300	11
XR Flat-fan 110°	224	310	250	22
Turbo Flat-fan	340	450	400	6
Drift Guard Flat-fan 80°	340	410	330	8
Drift Guard Flat-fan 110°	330	390	320	11
Flooding Flat-fan	-	450	410	3
TurboFlood Flat-fan	-	710	650	<1

Strategies to reduce drift

In addition to nozzle selection, there are many other operating variables that affect drift. There is no single “fits-all” combination that will work for every condition or application. However, there are strategies that, when combined, can work together to lower the potential for drift to occur. The best strategy is for the applicator to recognize conditions that are unfavorable for pesticide applications and make adjustments, if possible, or simply postpone the application. The following table outlines some common strategies that can reduce, but not eliminate, drift.

Table 5. Strategies to reduce drift

Recommendation	Example	Explanation
Select a nozzle that produces a uniform range of coarse droplets.	Flooding, turbulence-chamber, air-induction nozzles. (Turbo TeeJet, Raindrop, AI TeeJet, TurboDrop)	Use the largest droplets possible while maintaining adequate coverage of the intended target.
Use a lower boom height.	Use 110° tips instead of 80°. Maintain a uniform height that is low enough for even distribution above the target. Utilize drop-nozzles where conditions warrant.	Lower boom heights decrease the distance particles have to travel. Wind speed increases with height.
Use lower operating pressure	Use the low end of the pressure range recommended for the nozzle or switch to extended-range nozzles.	Higher pressure generates smaller droplets and a higher percentage below 100 microns.
Use larger nozzles	Use a higher application rate (GPA).	Larger nozzles allow the use of lower pressures
Avoid applying when winds are greater than 10 MPH or when any wind is blowing towards sensitive vegetation.	Use a wind gauge to accurately determine wind speed. Consider buffer zones near sensitive areas.	As wind speed increases droplets can move greater distances.
Do not spray when air is completely calm or inversions exist.	Inversions usually occur during early morning hours following clear nights, or near bodies of water.	Because inversions reduce mixing of surface air, small spray droplets can be carried long distances and deposited.

References

Bode, L. E. 1984. Downwind drift deposits by ground applications. Proceedings of the Pesticide Drift Management Symposium. South Dakota State University, Brookings, SD, p 50.

Derksen, R. C., H. E. Ozkan, R. D. Fox, and R. D. Brazee. 1997. Effectiveness of TurboDrop and Turbo TeeJet nozzles in drift reduction. American Society of Agricultural Engineers Paper No. 971070. St. Joseph, MI.

Hanna, H. M. 1997. Application equipment considerations for minimizing drift. Proceedings of the Minnesota Crop Pest Management Shortcourse. University of Minnesota, St. Paul, MN.

Spraying Systems Co. 1998. Agricultural Spray Products Catalog. Spraying Systems, Co., Wheaton, IL.

Wolf, R. E. 1996. New designs in pesticide application equipment for more efficient control and reduced drift. Proceedings of the Integrated Crop Management Conference. Iowa State University, Ames, IA. pp. 79-90.