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Spray Drift of Pesticides

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This NebGuide discusses conditions that cause particle drift, and methods private and commercial applicators can adopt to reduce drift potential from pesticide spray applications.

Spray drift of pesticides away from the target is an important and costly problem facing both commercial and private applicators. Drift causes many problems, including

1) damage to susceptible off-target sites;
2) a lower rate than intended on target, which can reduce the effectiveness of the pesticide and waste pesticide and money; and
3) environmental contamination, such as water pollution and illegal pesticide residues.

Drift occurs by two methods: vapor drift and particle drift. This NebGuide focuses on conditions that cause particle drift, and methods to reduce the drift potential when spraying pesticides. The potential for off-target movement needs to be a primary consideration for all pesticide applications.

Drift Dynamics

A solution sprayed through a nozzle atomizes into droplets that are spherical or nearly spherical in shape. Particle drift is the actual movement of spray particles away from the target area. Many factors affect this type of drift, but the most important is the initial droplet size. Small droplets fall through the air slowly and are carried farther by air movement.

The size of a droplet is measured in microns. Droplets with diameters smaller than 100 microns, about the diameter of a human hair, are considered highly driftable and are so small they cannot be readily seen unless in high concentrations, such as fog. As a result of the small size, drift is more dependent on the irregular movement of turbulent air than on gravity.

Table I shows the effect of droplet size on the rate of fall. The longer the droplet is airborne, the greater the potential for drift.

When leaving the nozzle, the solution may have a velocity of 60 feet per second (41 mph) or more. Unless the spray particles are electrostatically charged, there are two forces acting upon the emerging droplets. These forces, gravity and air resistance, greatly influence the deceleration and movement of spray droplets. Droplet speed is reduced by air resistance, which can also break up the droplets. After their initial speed slows, the droplets are more influenced by gravitational pull.

Table I. Effect of droplet size on drift potential (Grisso, et al., 2013).

Droplet Diameter (microns)	*Droplet Size **	*Time Required to Fall 10 Feet*	*Lateral Movement in a 3-mph Wind*
5	Fog (VF)	66 minutes	3 miles
20	Very fine (VF)	4.2 minutes	1,100 feet
100	Very fine (VF)	10 seconds	44 feet
240	Medium (M)	6 seconds	28 feet
400	Coarse (C)	2 seconds	8.5 feet
1,000	Extremely coarse (XC)	1 second	4.7 feet

*Droplet size categories in parentheses are based on the British Crop Protection Council (BCPC) and American Society of Agricultural and Biological Engineers (ASABE) droplet size classification now in use.

With lower boom heights, the initial speed may be great enough that the droplet reaches the target before drift occurs. Large droplets maintain a downward velocity longer than smaller ones, and are more likely to be deposited on the intended target. Small droplets evaporate quicker than large droplets, leaving minute quantities of the pesticide in the air *(Figure 1)*. In addition to realizing that spray droplet size is an important factor in reducing drift, an applicator should be aware that a nozzle will produce many different sizes of droplets.

Droplet Size Categories

A nozzle that produces only one size droplet is not available, despite many efforts to develop one. Volume median diameter (VMD) is a term used to describe the various droplet sizes

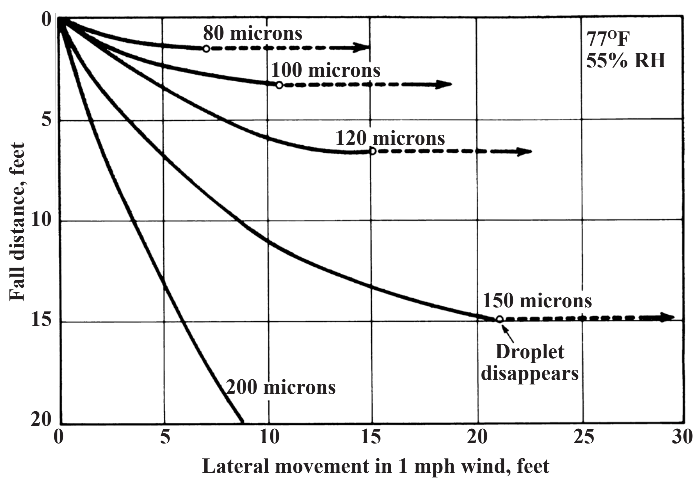

Figure 1. Lateral movement of water droplets. (Hofman and Solseg, 2004)

produced from a nozzle tip. VMD is the droplet size at which one-half the spray volume consists of droplets larger than the given value and one-half consists of droplets smaller than the given value. Since it takes many more small droplets to make up one-half the spray volume, there always will be more small droplets present in a typical spray pattern. Ideally, most of the volume should be contained in larger droplets, which is shown by a larger VMD.

The British Crop Protection Council (BCPC) and the American Society of Agricultural and Biological Engineers (ASABE) developed a droplet size classification system with categories ranging from extra fine to ultra coarse, based on VMD values measured in microns (*Table II*). Nozzle catalogs and guides often refer to these droplet size categories and color code descriptions to reduce confusion. An applicator can select the nozzle and pressure based on the droplet size category charts. In addition, the pesticide label may list the recommended droplet size category to use with a particular product. For example, the label statement might read: "Apply with 12 or more gallons per acre using a nozzle producing a coarse droplet." The label includes these spray category recommendations to make sure that the droplet size is suitable for pesticide efficacy, yet as large as possible to reduce the potential for drift. Typically, low-drift nozzles produce spray droplets in the medium (M) to extremely coarse (XC) range, while reducing the amount of fine droplets that would be likely to drift.

Table II. Droplet size classifications with color codes, based on BCPC specifications in accordance with ASABE Standards.

Category	*Symbol*	*Color Code*	*Approximate VMD Range (microns)*
Extremely Fine	XF	**Purple**	~50
Very Fine	VF	**Red**	<136
Fine	F	**Orange**	136-177
Medium	M	**Yellow**	177-218
Coarse	C	**Blue**	218-349
Very Coarse	VC	**Green**	349-428
Extremely Coarse	EC	**White**	428-622
Ultra Coarse	UC	**Black**	>622

Altering Droplet Size

Some sprayer components can be adjusted to alter droplet size. Nozzle type selection is one of the most influential means *(Table III)*. For more information on droplet sizes created under various conditions, download the University of Nebraska–Lincoln Extension smartphone app "Ground Spray" from the Apple App Store or the Google Play Store.

The following section covers ways to alter droplet size.

Nozzle Type

Spray droplets are produced from nozzles in different ways.

- A *flat-fan nozzle* forces the liquid under pressure through an elliptical orifice and the liquid spreads out into a thin sheet that breaks up into different-sized droplets. This type includes the venturi-type that relies on a pressure-against-orifice effect to atomize the spray.
- A *flood nozzle* deflects a liquid stream off a plate that causes droplets to form.
- A *whirl chamber nozzle* swirls the liquid out an orifice with a circular motion and aids the droplet formation with a spinning force.
- An *air inclusion nozzle* has one orifice to meter liquid flow and another larger orifice to form the pattern. Between these two orifices is a venturi or jet that draws air into the nozzle body. There, air mixes with the liquid and forms a spray pattern at a lower pressure. The coarse spray contains large, air-filled droplets and few drift-susceptible droplets.

Droplet sizes are influenced by various nozzle types and spray pressures. In *Table III*, of the three nozzles being compared, the Turbo TeeJet® produces the largest droplet, which results in the lowest drift potential. For many herbicide applications a large droplet gives good results, but for good plant coverage (i.e. postemergence application), large droplets may not give good pest control.

Table III. Effect of nozzle type on droplet size at 40 PSI and 0.5 GPM (*adapted from Spraying Systems Co., 2007).

Nozzle Type	*Volume Median Diameter, microns*
Hollow Cone	330 (*Coarse*)
Drift Guard	440 (*Extremely Coarse*)
Turbo TeeJet®	500 (*Extremely Coarse*)

*Droplet size categories in italics were added based on BCPC and ASABE droplet size classification now in use.

Spray Pressure

Spray pressure influences the formation of the droplets as well as droplet size. When boom or nozzle pressure is increased, a higher percentage of droplets are small. With a greater proportion of the total spray volume in smaller droplets, the potential drift to off-target sites increases. The spray solution emerges from the nozzle in a thin sheet, and droplets form at the edge of the sheet. Higher pressures cause the sheet to be thinner and break up into smaller droplets. Small droplets are carried farther downwind than larger droplets formed at lower pressures *(Figure 1)*. *Table IV* shows the mean droplet size for nozzles when spraying at three pressures. Higher pressures decrease the droplet size.

Orifice Size and Carrier Volume

Large orifice nozzles with higher carrier volumes produce larger drops. The relationship between flow rate (gallons per minute or GPM) and pressure (pounds per square inch or PSI) is not linear. For example, to double the flow rate would require the pressure to be increased by four times. This action would contribute to the drift potential and is not an acceptable method to increase carrier volume. If the carrier volume needs to be changed, select a different nozzle tip that meets the spraying requirements. Consult the pesticide label and *NebGuide G955, Nozzles — Selection and Sizing,* for proper selection.

Nozzle Spray Angle

The spray angle of a nozzle is the distance between the outer edges of the spray pattern, expressed as a number of arc degrees. (A full circle is 360°.) Wider angles cover a wider spray path and produce a thinner sheet of spray solution and smaller droplets at the same pressure *(Table IV)*. However, wide angle nozzles can be placed closer to the target, and the benefits of lower nozzle placement may outweigh the disadvantage of slightly smaller droplets. Lower pressures can be used to reduce the amount of fine droplets. For lower pressures with flat-fan nozzles, low pressure or extended range nozzles must be used.

Table IV. Effect of spray angle and pressure on droplet size (*adapted from Spraying Systems Co., 1990).

Nozzle Spray Angle Degrees	*Volume Median Diameter, microns*		
	15 PSI	*40 PSI*	*60 PSI*
40	900 (*UC*)	810 (*UC*)	780 (*UC*)
65	600 (*EC*)	550 (*EC*)	530 (*EC*)
80	540 (*EC*)	470 (*EC*)	450 (*EC*)
110	410 (*VC*)	380 (*VC*)	360 (*VC*)

*Droplet size categories in italics were added based on BCPC and ASABE droplet size classification now in use.

Spray Volume

The size or capacity of the nozzle also influences droplet size. A larger orifice increases the droplet size at a common pressure. Since a larger orifice uses more spray volume, it also increases the number of refills; however, the increased volume of carrier solution improves coverage, and in some cases increases pesticide effectiveness. *Table V* shows the influence of increasing flow rate on droplet size at a constant pressure. With some pesticides, such as glyphosate, performance is better at lower carrier volumes.

Table V. Effect of flow rate on droplet size at 40 PSI (*adapted from Spraying Systems Co., 2007).

	Volume Median Diameter, microns		
Nozzle Type	*0.3 GPM*	*0.4 GPM*	*0.5 GPM*
Extended Range Flat Fan	270 (*C*)	300 (*C*)	330 (*C*)
Drift Guard	400 (*VC*)	425 (*EC*)	450 (*EC*)
Turbo TeeJet	450 (*EC*)	480 (*EC*)	510 (*EC*)

*Droplet size categories in italics were added based on BCPC and ASABE droplet size classification now in use.

Other Drift Factors

Boom Height

Operating the boom as close to the sprayed surface as possible while staying within the manufacturer's recommendation will reduce the potential for drift. A wider spray angle allows the boom to be placed closer to the target *(Table VI)*. Booms that bounce cause uneven coverage and drift. Wheel-carried booms stabilize boom height, which reduces the drift hazard, provides more uniform coverage, and permits lower boom height. Boom height controllers are now optional on many sprayers.

Table VI. Suggested minimum spray heights above spray contact surface.

	Spray Height, inches			
	20-inch Nozzle Spacing		*30-inch Nozzle Spacing*	
Spray Angle Degrees	*30% overlap*	*100% overlap*	*30% overlap*	*100% overlap*
65	22-24	-NR-	-NR-	-NR-
73	20-22	-NR-	29-31	-NR-
80	17-19	26-28	26-28	-NR-
110	10-12	15-17	14-18	25-27

NR — Not recommended if height is above 30 inches

Nozzle Spacing

This is the distance between nozzles on a spray boom. Nozzle spacing is critical to achieving adequate spray coverage. Spray angle and boom height also are key factors in coverage. Nozzle spacing for a given spray volume requires an increase in orifice size as the spacing increases. This typically means increasing the boom height to get the proper overlap. However, enlarging the droplet size is more important than increasing boom height.

Follow the equipment and nozzle manufacturer's recommendations for appropriate nozzle configuration. As a general guideline, do not exceed a 30-inch nozzle spacing because the spray pattern will not be as uniform. A configuration of nozzle spacing, height, and direction that gives 100 percent overlap is preferred. The best nozzle spacing for most sprayers is 15 inches. Specifically, for high volumes use a 15-inch nozzle spacing and for low volumes, cap off every other nozzle and use a 30-inch nozzle spacing.

Wind Speed

Both the amount of pesticide lost from the target area and the distance it moves increase as wind velocity increases *(Table VII)*. However, severe drift injury can occur with low wind velocities, especially under temperature inversion situations. Most recommendations are to stop spraying if wind speeds are less than 3 mph or exceed 10 mph. Some product labels have application restrictions when winds are higher than 8 mph. The wind effect can be minimized by using shielded booms and a lower boom height.

Table VII. Effect of wind speed on drift in a 10-foot fall (*adapted from Ross and Lembi, 1985)

	Drift	
Droplet Diameter	*1 mph Winds*	*5 mph Winds*
Microns	*feet*	
100 (Mist) (*VF*)	15	77
400 (Coarse Spray) (*VC*)	3	15

*Droplet size categories in italics were added based on BCPC and ASABE droplet size classification now in use.

Wind Direction

Pesticides should not be applied when the wind is blowing toward a nearby susceptible crop or a crop in a vulnerable stage of growth. Select a time when there is little wind or the wind blows gently away from susceptible crops. If these conditions do not exist, consider another method of control or time of application.

Air Stability

Air movement largely determines the distribution of spray droplets. Often wind is recognized as an important factor, but vertical air movement is overlooked. Temperature inversion occurs when cool air near the soil surface is trapped under a layer of warmer air. A strong inversion potential occurs when ground air is 2°F to 5°F cooler than the air above it and there is no wind.

Under inversion conditions there is little vertical mixing of air, even with a breeze. Spray drift can be severe. Small spray droplets may fall slowly or be suspended and move several miles to susceptible areas, carried by a gentle breeze. Do not apply pesticides near susceptible crops during temperature inversion conditions. Identify an inversion by observing smoke from a smoke bomb or a fire *(Figure 2)*. Smoke moving horizontally close to the ground indicates a temperature inversion.

Relative Humidity and Temperature

Low relative humidity and/or high temperature conditions cause faster evaporation of spray droplets and a higher potential for drift. During evaporation, the spray solution loses more water than pesticide, creating smaller droplets with a greater concentration of pesticide. The quantity of spray that evaporates from the target surface is related to the quantity of spray deposited on that surface. Smaller droplets, being more prone to drift and evaporation, have less chance of actually being deposited on the target surface than do large droplets. Therefore, hot and dry weather conditions lead to less spray deposition and more drift, due to evaporation of the spray carrier solution.

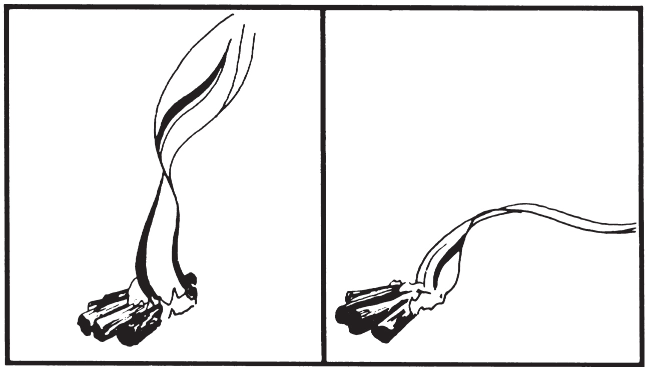

Figure 2. Smoke rising with wind velocity below 5 mph.

Evaporation increases the potential for drift so spray during lower temperature and higher humidity conditions. Pesticides differ in their evaporation rate. Use formulations and adjuvants that reduce evaporation. Some pesticide labels specify relative humidity and temperature conditions for product use. Generally, if the relative humidity is above 70 percent, conditions are ideal for spraying. A relative humidity below 50 percent is critical enough to warrant special attention.

Spray Thickeners

Some spray adjuvants act as spray thickeners or drift retardants when added to a spray tank. These materials increase the number of larger droplets and decrease the number of fine droplets. They tend to give water-based sprays a "stringy" quality and reduce drift potential. Droplets formed from an oil carrier tend to drift farther than those formed from a water carrier. Oil droplets are usually smaller, lighter, and remain airborne for longer periods, but don't evaporate quickly.

Best Management Practices to Avoid Pesticide Drift

All nozzles produce a range of droplet sizes. The small, drift-prone particles cannot be eliminated but can be reduced and kept within reasonable limits. Here are some tips:

1. Select low or nonvolatile pesticides.
2. Read and follow the pesticide label. Instructions on the pesticide label are given to ensure the safe and effective use of pesticides with minimal risk to the environment. Each pesticide is registered for use on specific sites or locations. Many drift complaints involve application procedures in violation of the label.
3. Use spray additives within label guidelines. This will result in better pesticide effectiveness and less potential for drift.
4. Use nozzles with larger orifice sizes. This will produce larger droplets and increase the number of tank refills, but may improve coverage and effectiveness while reducing the potential for drift.
5. Avoid high spray boom pressures; high spray pressure creates finer droplets. Consider 45 PSI the maximum for conventional broadcast ground spraying.
6. Use drift-reduction nozzles that produce larger droplets when operated at low pressures. When using venturi nozzles, higher pressures will be required to maintain an effective pattern. As the pressure is increased with these nozzles, the drift potential will increase, but not as much as with other types of nozzles.
7. Use wide-angle nozzles, low boom heights, and keep the boom stable. Drive perpendicular to terraces rather than parallel to avoid moving the boom ends high above the target surface or digging into the ground.
8. Drift is minimal when wind velocity is between 3 mph and 10 mph. Do not spray when temperature inversions are likely or when wind is high or blowing toward sensitive crops, gardens, dwellings, livestock, or water sources.
9. Use shielded booms. When banding, use shroud covers.
10. When possible, use lower application speeds. As application speed increases, there are often unintended effects on other application parameters that may increase drift.

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