G1773

Spray Drift of Pesticides

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> This NebGuide discusses conditions that cause particle drift, and methods private and commercial applicators may employ 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, 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 mainly on conditions that cause particle drift, and methods to reduce the drift potential of spraying pesticides.

Drift Dynamics

A solution sprayed through a nozzle divides into droplets that are spherical or nearly spherical in shape. A recognized measure for indicating the size of these droplets is micron size.

Droplets smaller than 100 microns, about the diameter of the human hair, are considered highly driftable and are so small they cannot be readily seen unless in high concentrations, such as fog. By comparison, a dime is about 1,270 microns thick. As a result of the small size, drift is more dependent on the irregular movement of turbulent air than on gravity.

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 size of the droplet. Small droplets fall through the air slowly, and are carried farther by air movement.

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

Table I. Effect of droplet size on drift potential (Ross and Lembi, 1985)

Diameter, microns	Time to fall 10 feet in still air
1 (Fog)	28 hours
10 (Fog)	17 minutes
100 (Mist)	11 seconds
200 (Fine Spray)	4 seconds
400 (Coarse Spray)	2 seconds
1,000 (Coarse Spray)	1 second

acting upon the emerging droplets. These forces — gravity and air resistance — greatly influence the speed and movement of spray droplets.

Droplet speed is reduced by air resistance, which breaks up the droplets. After their initial speed slows, the droplets continue to fall under the gravitational pull.

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. Small droplets also evaporate quickly, leaving minute quantities of the pesticide in the air *(Figure 1)*. Larger droplets are more likely to be deposited on the intended target.

Ideally, most of the volume should be contained in larger droplets. When pressure is increased, a higher percentage of droplets are small droplets. With a greater proportion of the total spray volume in smaller droplets, the potential drift onto off-target sites increases.
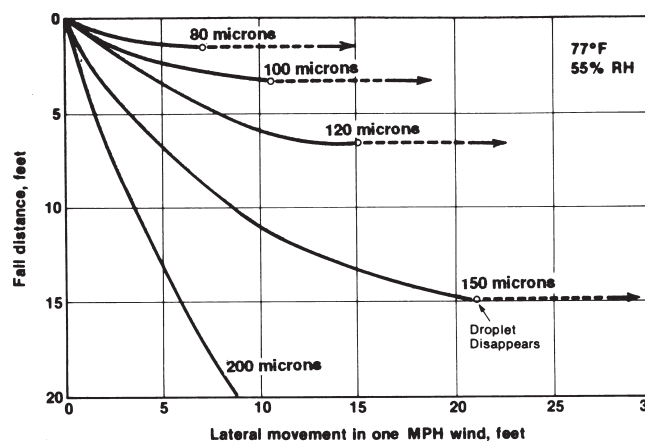

Figure 1. Lateral Movement of water droplets. (Hofman, et al., 1986)

Altering Droplet Size

Many components of a sprayer can be adjusted to alter droplet size. Of these, nozzle type selection is one of the most critical.

- **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.
- 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.

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

Nozzle Type	Volume Median Diameter, microns
Hollow Cone	330
Drift Guard	440
Turbo TeeJet	500

Volume median diameter (VMD) is a term used to describe the droplet size produced from a nozzle tip. VMD is the droplet size at which one-half the spray volume consists of large droplets and one-half consists of smaller droplets. 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.

Droplet sizes are influenced by various nozzle types and different spray pressures. The Turbo TeeJet cone produces the largest droplets of the three, which results in lower 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.

Remember, nozzles produce a wide range of droplet sizes. A nozzle that can produce only one size droplet is not presently available. Therefore, the goal in the proper application of pesticides is to achieve a uniform spray distribution while retaining the spray droplets within the intended target area.

- **Spray Pressure:** Spray pressure influences the formation of the droplets. 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 the sheet breaks up into smaller droplets.

Large orifice nozzles with higher carrier volumes produce larger drops. Small droplets are carried farther downwind than larger drops formed at lower pressures *(Figure 1)*.

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 greatly contribute to the drift potential and is not an acceptable method to increase carrier volumes. If the carrier volume needs to be changed, select a different nozzle tip that meets the spraying requirements. Consult *NebGuide G955, Nozzles — Selection and Sizing,* for proper selection.

Table III shows the mean droplet size for nozzles when spraying at three pressures. Higher pressures decrease the droplet size.

- **Nozzle Spray Angle:** Nozzles that have wider spray angles produce a thinner sheet of spray solution and smaller droplets at the same pressure *(Table III)*. However, wide angle nozzles can be placed closer to the target, and the benefits of lower nozzle placement 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 III. Effect of spray angle and pressure on droplet size (Spraying Systems Co., 1990)

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

- **Spray Volume:** The size or capacity of the nozzle also influences droplet size. The larger orifice increases the droplet size at a common pressure. It increases the number of refills, but the added carrier improves coverage and in some cases increases pesticide effectiveness. *Table IV* shows the influence of an increasing flow rate on droplet size at a constant pressure. With some pesticides, such as glyphosate, the carrier must be kept low.

Table IV. Effect of flow rate on droplet size at 40 PSI (Spraying Systems Co., 2007)

Nozzle Type	Flow Rate		
	0.3 GPM	0.4 GPM	0.5 GPM
	Volume Median Diameter, microns		
Extended Range Flat Fan	270	300	330
Drift Guard	400	425	450
Turbo TeeJet	450	480	510

Other Drift Factors

- **Boom Height:** Operating the boom as close to the sprayed surface as possible — staying within the manufacturer's recommendation — is a good way to reduce drift. A wider spray angle allows the boom to be placed closer to the target *(Table V)*. 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. Shielded booms reduce the drift from excessive air movement from travel speed and wind.

Table V. Suggested minimum spray heights. (NebGuide G955)

Spray Angle Degrees	20 inches 30%	20 inches 100%	30 inches 30%	30 inches 100%
	Percent Overlap			
	Spray Height, inches			
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:* 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.

As a general guideline, do not exceed a 30-inch nozzle spacing because the spray pattern uniformity begins to degrade. A configuration of nozzle spacing, height and direction, which gives 100 percent overlap, is preferred.

• *Wind Speed:* The amount of pesticide lost from the target area and the distance it moves both increase as wind velocity increases *(Table VI)*. However, severe drift injury can occur with low wind velocities, especially under temperature inversion situations. Most recommendations are to stop spraying if wind speeds exceed 10 mph. Wind influences can be minimized by using shielded booms and lower boom height.

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

Droplet Diameter, microns	1 MPH	5 MPH
	Wind Speed	
	Drift, feet	
100 (Mist)	15.4	77
400 (Coarse Spray)	3.0	15

• *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. Wind generally is recognized as an important factor, but vertical air movement often 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.

Under inversion conditions, little vertical mixing of air occurs, 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.

Avoid applying pesticides near susceptible crops during temperature inversion conditions. Inversions can be identified by observing smoke from a smoke bomb or a fire *(Figure 2)*. Smoke moving horizontally close to the ground would indicate a temperature inversion.
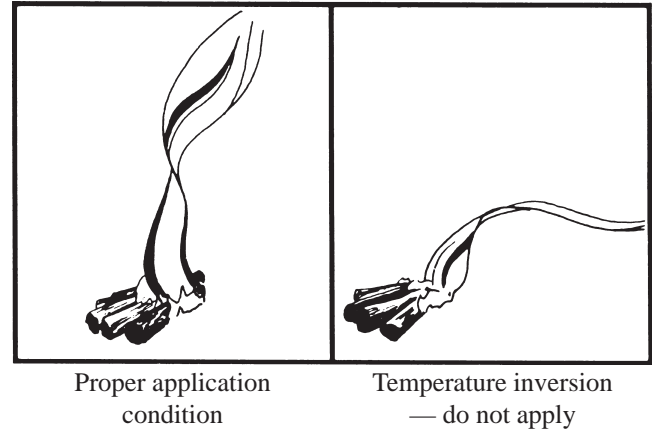

Proper application condition   Temperature inversion — do not apply

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

• *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 droplets become smaller.

The quantity of spray that evaporates is related to the quantity of the spray deposit. Evaporation is greater from the same deposit in small droplets than in larger drops because the small droplets have greater surface area relative to their volume. Less pesticide gets to the target *(Figure 1)*.

Evaporation increases the drift potential, so spray during lower temperature and higher humidity conditions. Pesticides differ in their evaporation rate. Use formulations and adjuvants that reduce evaporation.

As a rule of thumb, if the relative humidity is above 70 percent, the 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 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 Concerning 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. Surveys indicate approximately 65 percent of drift complaints involved application procedures in violation of the label. Apply a pesticide only if economic thresholds warrant an application.

3. Use spray additives within label guidelines. This will increase the droplet sizes and pesticide effectiveness.

4. Use larger orifice sizes. This will give larger droplets and increase the number of tank refills, but will improve coverage and effectiveness.

5. Avoid high pressure. High pressure creates finer droplets; 45 PSI should be considered maximum for conventional broadcast spraying.

6. Use drift-reduction nozzles. They will produce larger droplets when operated at low pressures.

7. Use wide-angle nozzles, low boom heights, and keep the boom stable.

8. Drift is minimal when wind velocity is under 10 mph. Do not spray when wind is greater or blowing towards sensitive crops, gardens, dwellings, livestock or water sources.

9. Use shielded booms. When banding, use shroud covers.

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Weight and Measure Conversions

Weight
- 16 ounces = 1 pound = 453.6 grams
- 1 gallon water = 8.34 pounds = 3.78 liters

Liquid measure
- 1 fluid ounce = 2 tablespoons = 29.57 milliliters
- 1 tablespoon = 3 teaspoons
- 16 fluid ounces = 1 pint = 2 cups
- 8 pints = 4 quarts = 1 gallon

Length
- 3 feet = 1 yard = 91.44 centimeters
- 16.5 feet = 1 rod
- 5,280 feet = 1 mile = 1.61 kilometers
- 320 rods = 1 mile

Area
- 9 square feet = 1 square yard
- 43,560 square feet = 1 acre = 160 square rods
- 1 acre = 0.405 hectare
- 640 acres = 1 square mile = 1 section

Speed
- 88 feet per minute = 1 mph
- 1 mph = 1.61 km/hour

Volume
- 27 cubic feet = 1 cubic yard
- 1 cubic foot = 1,728 cubic inches = 7.48 gallons
- 1 gallon = 231 cubic inches
- 1 cubic foot = 0.028 cubic meters

Common abbreviations and terms:
- FPM = feet per minute
- GPA = gallons per acre
- GPH = gallons per hour
- GPM = gallons per minute
- MPH = miles per hour
- PSI = pounds per square inch
- RPM = revolutions per minute
- VMD = volume median diameter

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