# Chapter 29

## Pesticide Application Equipment

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Conservation tillage does require some adjustments in pesticide application equipment over intensive tillage systems. Because soil incorporation of herbicides can destroy crop residue, most conservation tillage systems use contact herbicides and/or residual herbicides that are carried into the soil by rainfall or irrigation. The use of herbicide resistant crops has reduced the need for many soil-incorporated herbicides. Applying herbicides in heavy residue does not require additional active ingredients but may require higher spray volumes for coverage and penetration of crop residue.

No matter what pesticide is selected, proper adjustment of equipment and selection of product is critical for satisfactory performance. Inaccurate pesticide application is expensive. It can result in wasted pesticide, marginal pest control, and excessive carryover contributing to water contamination and/or crop damage.

Accurate pesticide application first depends on the delivery unit that has all its major components such as pump, filter, agitation system, control or throttling system, and pressure gauge in excellent operating condition. Once a sprayer is properly equipped, pesticide can be applied accurately if the interrelationships of five factors are considered prior to and during application:

1. Boom height.
2. Nozzle pattern, type and size.
3. Nozzle pressure/flow rate.
4. Ground speed.
5. Properly mixed pesticides.

Pesticides are applied correctly when these five factors are in the correct combination.

Preseason visual checks of application equipment do not ensure accurate application, and neither does new equipment or nozzle tips. National surveys show that only one of three sprayer operators applied pesticides within 5% of their intended rate. Calibrating and fine-tuning a sprayer are the operator’s responsibilities.

Keep spray equipment in good condition; calibrate frequently, and operate as recommended for specific field conditions. Manufacturers’ manuals include tables to show spray rates in gallons per acre (gpa) for various nozzles, pressures, and ground speeds under ideal conditions. Use this information to adjust the sprayer, then calibrate to evaluate and fine-tune the sprayer for accurate application.

Calibrate the sprayer prior to changing to a different pesticide, and review the mixing and application instructions on the label. Also, calibrate the sprayer if field conditions change because soil conditions greatly influence travel speed. In addition, check a sprayer at least every other day when in continuous use. Because these checks are performed often, checking a sprayer quickly without excessive investment in equipment or calculation is very important. There are several calibration techniques. Check with your local Cooperative Extension Service for detailed methods of sprayer calibration.

Directed and Band Application

Directed and band application refers to targeting a specific portion of the field such as strips or rows. A treated acre refers only to the treated area in that acre. Figure 29-1 shows several methods and nozzle configurations used to apply pesticides.

Unless otherwise specified, pesticide application rates on the label are on a broadcast basis. For band applications, the rate per treated area is the same as the broadcast rate, but the total amount of pesticide used on a field is less because only a portion of the field is actually treated. When compared to broadcast application, banded application reduces pesticide cost. Cost savings result from not treating a whole field with pesticides.

Nozzle arrangement and type depend on the pesticide applied. For example, during insecticide or fungicide applications, the goal is total crop coverage. This type of application requires nozzles that produce relatively small droplets directed onto the crop. However, when applying herbicides, focus nozzles on the weeds at ground level so that the row crop intercepts less herbicide. The nozzles arranged with drop hoses or thin metal strips should be rigid enough to reduce twisting and rotating of the nozzles. This movement has the potential to decrease uniformity of spray pattern and could cause drift.

Banding Herbicides While Planting

Use even, flat-fan nozzles for band application because they provide a uniform application across the entire band width. Mounting height of the
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While Planting

Postemergence Application

A nozzle is critical in controlling band width. Mounting the nozzle too low results in a narrow band, potential nozzle damage, and over-application of herbicide. Mounting the nozzle too high results in a wider band, under-application of herbicide, and increased drift potential. Use Table 29-1 to establish an initial setting, then fine-tune the band width with the unit running. The resulting band width can be influenced by spray pressure. Always make a field check of the nozzle performance. Banding the crop rows and controlling weeds between the rows with cultivation (Chapter 28, Crop Cultivators) may be an economic alternative to broadcast spraying.

**Table 29-1. Band width and approximate nozzle height adjustments for various spray angle nozzles.**

<table>
<thead>
<tr>
<th>Band width, inches</th>
<th>Spray angle, degrees</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>40</td>
</tr>
<tr>
<td>8</td>
<td>10</td>
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<td>15</td>
<td>19</td>
</tr>
<tr>
<td>16</td>
<td>20</td>
</tr>
</tbody>
</table>

**Coverage**

coverage than a single nozzle (Figure 29-2). When the crop is taller than 3 inches, remove the top or center nozzle and use a two-nozzle configuration to reduce the risk of crop injury. The crop will intercept less herbicide. When applying fungicides and insecticides, use all three nozzles for thorough coverage of plant surfaces.
Herbicide Incorporation for Mulch-till

Heightened concerns for economics and soil conservation have caused producers to reduce the number of secondary tillage operations while trying to maintain satisfactory incorporation of herbicides. Many herbicides do not require mechanical incorporation because they are formulated to be carried into the soil by rainfall or sprinkler irrigation. However, some soil-applied herbicides require mechanical incorporation to reduce volatilization and photodecomposition losses. Product labels clearly specify directions for use, including whether incorporation is required or not.

Soil Mixing

Many herbicides are labeled for single-pass incorporation that minimizes the amount of residue that is covered. The success of single-pass incorporation largely depends on the extent of soil and herbicide mixing. Adequate mixing is unlikely if equipment is operated too slowly, at too shallow a depth, or on soil that is too wet. These errors result in streaks of herbicides and weed escapes.

There are two commonly used approaches to herbicide incorporation:
1. Complete incorporation.
2. Shallow incorporation, commonly called surface mixing.

Complete incorporation calls for all of the herbicide to be thoroughly mixed to a depth of 2 to 3 inches. Shallow incorporation, on the other hand, involves shallower and less complete mixing. Shallow incorporation improves horizontal distribution.

Single-pass incorporation in soybean stubble is usually successful, especially when soil is dry. However, a single pass decreases residue below 30%; thus herbicide incorporation in soybean stubble should be limited to relatively flat areas where soil erosion is minimal. Heavy cornstalks and grain sorghum stubble (125 bushel per acre) will usually have about 30% cover after two passes. However, improved weed control with multi-pass incorporation results in loss of soil moisture, less erosion control, and extra expense of machine operation and labor.

Single-pass incorporation is more effective on relatively dry soils. Equip the tillage implement with a leveling device (harrow) to reduce herbicide streaking and operate at 6 to 7 mph for improved incorporation.

Incorporate volatile herbicides 2 to 3 inches deep; mix less volatile herbicides 1 to 2 inches deep. Incorporate root-absorbed herbicides at either depth. Mixing depth varies with implement and soil conditions. In unfavorable conditions such as wet soil and/or heavy residue, another pass may be required. For example, Treflan requires two incorporation passes in heavy residue, and one tillage pass may be required before application. The mixing depth is not the same as the operating depth. Typically, incorporation depth is about two-thirds the operating depth of the tillage implement.

Selecting Equipment for Applying Herbicides During Tillage

Herbicide incorporation during tillage requires correct nozzle selection, proper tillage implement adjustments, and proper nozzle mounting, spacing,
and orientation on the tillage implement. Examine the implement for potential limitations prior to selecting spray components. These limitations include possible interference of the spray pattern by the implement frame or tongue, limited places to mount the nozzles, and lack of clearance between the implement and rear tractor tires when turning. Proper nozzle selection and setup can lessen many of these influences.

Because nozzles must operate in a dusty environment, select a nozzle type that performs in spite of dust around the orifice. Turbo flooding flat-fan and Raindrop RA hollow-cone nozzles are most commonly used for soil-incorporated herbicide applications. Other recommended nozzles include the standard flooding flat-fan, full-cone, and extended range flat-fan nozzles.

Turbo flooding flat-fan nozzles provide a fanlike tapered edge pattern and will operate within a pressure range of 10 to 30 psi effectively. At common operating pressures, turbo flood nozzles produce droplets that are 30 to 50% larger than those produced by a standard flood nozzle. Mount turbo flooding flat-fan nozzles to spray straight down and place at a height that provides approximately 50% overlap. Use Table 29-2 to find a first approximation for nozzle arrangement and then adjust nozzle height until 50% overlap of the spray pattern is achieved. This will result in an excellent pattern on the surface. The turbo flooding flat-fan nozzle is an excellent choice over standard flood nozzles for soil incorporation of herbicides.

Standard flood nozzles provide a fanlike spray pattern and operate at 10 to 25 psi. When a standard flood nozzle sprays straight down, a greater concentration of herbicide occurs along the edges of the spray pattern. Rotate the nozzles 30 to 45 degrees so the spray is forward to the direction of travel (Figure 29-3) to improve the uniformity. Space flood nozzles no more than 60 inches apart.

Raindrop nozzles are hollow-cone type nozzles with spray angles of between 115 and 125 degrees. Mount Raindrop nozzles with a spacing and orientation to achieve 100% overlap (Figure 29-3) to ensure adequate coverage as the implement moves across uneven ground. A typical orientation would be from 30 to 45 degrees forward from vertical.

Select a nozzle height and spacing for various implements widths using Table 29-2. If necessary, decrease nozzle spacing, and reduce height to prevent the implement frame or tongue from interfering with the spray pattern.

Base nozzle selection on operating speed, operating height, implement width, and label spray rate recommendations. Select a nozzle that delivers the desired discharge at the desired speed. Most nozzle catalogs list the broadcast spray rate for a 40-inch nozzle spacing. If the nozzle spacing is not 40 inches, divide the desired broadcast spray rate by the conversion factors in Table 29-2 to compare the broadcast spray rate listed in the catalog.

**Equipment Adjustment-Soil Incorporated**

Equipment selection, assembly, and operation are the most important factors in obtaining uniform herbicide incorporation. Adjust equipment in the field for the specific field conditions. Previous crop, amount of residue, soil type, drainage, previous tillage operations, and weather influence equipment adjustments.
Level the implement, both front to back and side to side. Adjust to desired operating depth (1 to 6 inches), depending on the implement and herbicide. Adjust operating depth as the soil and residue moisture conditions change during the day. If wheel hydraulic cylinders do not have stop adjustments, install them for precise resetting of depth.

Adjust adjoining implement wings to operate at the same depth as the center tillage unit. Lighter implement wings tend to ride up and operate at less depth than the center unit. Eyebolt adjustments on wing cylinders, wing-tire deflation, changing wing-tire size, or adding weight to the wings can bring the wings in line with the center unit. Unequal tire sizes across the tool may make adjustments impossible. Replace tires if necessary to achieve proper adjustment.

Adjust implements so that all soil is worked across the entire tool width. A misplaced shank, a broken tine, or a worn tillage component results in nonuniform incorporation. It may be necessary to move a field cultivator shank over slightly or add a shank behind equipment tires to till the tire tracks for more uniform incorporation.

Ground speed and operating depth determine the extent of soil mixing and herbicide distribution accomplished by a particular tillage implement. In general, a speed of greater than 6 mph is recommended for proper incorporation. As the optimum speed of operation is approached, mixing and horizontal distribution increase. Above the optimum speed, horizontal distribution decreases because depth is difficult to maintain at higher speeds.

### Table 29-2. Nozzle arrangements.
Arrangements for various tillage implements when using nozzles with a 120° spray angle.

<table>
<thead>
<tr>
<th>Implement width, feet</th>
<th>Number of nozzles</th>
<th>Nozzle spacing, inches</th>
<th>Nozzle height, inches</th>
<th>40° nozzle spacing conversion factor</th>
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</thead>
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<td>36.0</td>
<td>12.0</td>
<td>1.11</td>
</tr>
<tr>
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<td>0.95</td>
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<td>8</td>
<td>2</td>
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<td>16.0</td>
<td>0.83</td>
</tr>
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</tr>
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<tr>
<td>35</td>
<td>10</td>
<td>42.0</td>
<td>14.0</td>
<td>0.95</td>
</tr>
</tbody>
</table>

*aThese heights do not allow a 100% overlap. To increase overlap for more uniform distribution, tilt the nozzles forward and/or raise the height until 100% overlap is achieved.

Example 29-1:
Convert desired broadcast spray volume to broadcast spray volume with 40-inch nozzle spacing.

To apply 10 gpa with nozzles spaced 36 inches apart, divide the desired broadcast spray volume, 10 gpa by the conversion factor listed in Table 29-2 for 36-inch nozzle spacing, 1.11, to get 9.0 gpa. Look for this value in Table 29-3. In this example, a number 3 nozzle tip will apply 9.0 gpa when operated at 20 psi pressure and with a 7 mph travel speed. The size 3 tip will apply 10 gpa when nozzles are on 36-inch spacing if it is operated at the same 20 psi pressure and a 7 mph travel speed. Use this procedure for selecting nozzles for spacings other than 40 inches.
Often, tillage equipment is larger than the tractor can pull at the speeds necessary for proper incorporation. On hilly ground or when soil conditions are less than optimum, speed is reduced and incorporation uniformity suffers. Choose a tillage implement smaller than is typically matched with your tractor to allow additional power to transport a spray tank and spray solution and to operate sprayer accessories.

**Aerial Application**

There are presently about 6,000 airplanes and 400 helicopters used in the agricultural aviation industry in the United States. Aerial application accounts for about 25% of pesticide spray applications. Cotton and rice producers depend heavily on aerial application. Rice is almost totally fertilized and seeded by air. Cotton, rice, wheat, vegetables, corn, soybeans, and sorghum account for about 70% of the agricultural aviation activities.

Some of the advantages of aerial application are the ability to cover large acreages rapidly (which may be critically important during pest outbreaks), the ability to treat fields during wet conditions, and the elimination of soil compaction (no wheel traffic) caused during application.

Some of the disadvantages are the cost of application equipment, the special training (i.e. pilot’s license) required to operate equipment, and the impracticality of treating fields close to urban areas due to concerns about drift and noise.

The application equipment used in aerial application is similar to that used on ground equipment; therefore, many of the same principles and concerns apply. Among these concerns are the need for accurate calibration and patterning of the equipment, drift mitigation, and properly maintaining equipment. The equipment consists of a hopper for the spray solution, a pump to pressurize the system, a spray boom, and spray nozzles to deliver the desired rate of material. The spray rates are generally lower in aerial applications with the majority of rates being in the 1 to 5 gallons per acre range, although some applications are made at 10 gallons per acre. The main difference between ground and aerial applications is the high wind conditions.
shear present during aerial applications. Wind shear greatly changes the droplet spectrum produced, with the droplet size generally being reduced. New nozzle designs are overcoming many wind shear issues.

Aerial application technology has changed significantly in recent years. Global Positioning Systems (GPS) are increasingly being used to lessen the need for human flaggers, to provide a record of the application event, and to increase the overall accuracy of each application. Flow control devices coupled to GPS systems also are starting to be installed on more aircraft each year. These devices correct the flowrate based on ground speed, which can change when the aircraft is flying into or with the wind. In the past five years, the percentage of large, highly-productive agricultural aircraft in the agricultural aviation fleet has doubled. Larger turbine-powered aircraft are more productive due to increased speeds, wider swaths, and larger hoppers.

In the past five years, spray drift incidents have increased to the extent that spray drift is cited as the number one problem in the agricultural aviation industry. State records indicate that the major portion of aerial spray drift incidents is associated with turbine-powered aircraft. The switch to turbine-powered aircraft is being made because of economic pressures, with the larger aircraft being more productive and more efficient.

Spray Drift Management

Spray drift occurs wherever liquid sprays are applied. Although complete elimination of spray drift is impossible, potential problems can be minimized if chemicals are applied with the proper equipment under favorable weather conditions. Drift is undesirable for economic, environmental, and safety reasons. Today’s chemicals are more potent and require more precision during application. Unsatisfactory pest control could result if a significant portion of the chemical is lost in drift; unsatisfactory pest control could result in respraying. Producers may be held liable in court if spray drift damages sensitive crops in a neighboring field.

The environmental effects of spray drift are equally costly and unacceptable. Minimizing drift reduces the potential for polluting streams, lakes, and other water supplies and thereby endangering fish and wildlife.

Regardless of how accurate an application is made, the possibility of drift is always present. Minimize the possibility by selecting the proper equipment and using sound judgment when applying pesticides. Good judgment can mean the difference between an efficient, economical application and one that results in drift, damaging non-target crops and creating environmental pollution. Increased awareness of environmental quality and better understanding of the causes of spray drift can help you make sound judgments for safer, more efficient applications.

What is Drift?

Spray drift is generally defined as movement of a pesticide through the air, during or after application, to a site other than the intended site of application. The affected area is usually limited to the very close proximity of the area where pesticides are applied. However, under certain conditions, off-target movement may affect areas at greater distances from the application site. Problems occur when this movement affects a sensitive crop or another person’s property.

Sometimes, pesticides may leave the application area in the form of vapor. However, this type of drift becomes a significant concern only if the pesticide applied is highly volatile and the atmospheric conditions become suitable for rapid vaporization of the pesticide.

What Factors Influence Creation/Reduction of Drift?

Many factors influence drift: spray characteristics, equipment and application techniques, weather, and operator care and skill. Here are the factors that play a primary role in the creation of drift.

Droplet Size

Spray droplet size is by far the most important factor affecting drift. Spray droplet diameters are measured in microns. One micron is equal to 1/25,000 of an inch. As a reference, the thickness of a human hair or a sheet of paper is roughly 75 to 100 microns. The specific droplet size when drift potential becomes a significant issue depends on wind speed, but most researchers agree that droplets smaller than 200 microns are prone to drift even when wind speeds are less than 10 mph. Small droplets can drift long distances because of
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Spray droplets under 50 microns in diameter can remain suspended in the air indefinitely or until they evaporate. These small droplets should be avoided because there is no way to control deposition. For instance, there is no need to use small droplets when applying systemic herbicides. However, small-to-medium sized droplets may be desirable when applying insecticides and fungicides because this sized droplet provides better penetration into the canopy and better coverage. Complete coverage is essential with insecticides and fungicides because of the small size of the target organism.

Attain a balance between drift reduction provided by large droplets and good coverage provided by small droplets. Generally, spray-droplet size should be no finer than necessary to do an effective job. Recommended droplet sizes are 150 to 250 microns for fungicides, 200 to 300 microns for insecticides, and 250 to 400 microns for herbicides.

Nozzle Type and Size

Drift can be minimized in many ways; one of which is choosing the proper type and size of the nozzle for the job. Turbo flood-fan and wide-angle full-cone nozzles produce fewer drift-prone droplets than do hollow-cone nozzles and flat-fan nozzles. Nozzle manufacturers have recently developed what is called “low-drift” flat-fan nozzles (Drift Guard, Turbo flat-fan, TurboFlood, and Venturi nozzle, etc.).

Most manufacturers offer a venturi-based nozzle (Figure 29-4) that distributes small air bubbles into the droplets. All versions of venturi nozzles meter liquid flow with a pre-orifice into a constricted chamber. Pressure is reduced as it flows past the constriction (venturi) and draws in small amounts of air through small vents.

Most manufacturers have targeted VMD droplet sizes in the range of 350 to 600 microns. This is compared to standard flat-fan nozzles with a VMD of 150 to 350 microns. The venturi nozzles reduce the percentage of spray droplets in the fine category.

Spray Height

Small spray droplets have low inertial energy, making them highly susceptible to drift. In addition, wind velocity is usually greater as height above the ground increases. Therefore, the closer the nozzles are to the ground, the more the likelihood of spray pesticide drift is minimized. However, lowering the spray boom without adjusting nozzle spacing may result in improper spray overlap, which will cause streaks of untreated areas, especially with flat-fan nozzles. This problem can be eliminated by using nozzles with a wider fan angle.

Figure 29-4. Venturi-based nozzle. (Source: Greenleaf Technologies, Covington, LA)
Spray Pressure

Increased pressure generally decreases droplet size. One study of a flat-fan nozzle with a 0.6 gpm flow rate demonstrated that increasing the pressure from 20 to 40 psi increased the volume of droplets in the less-than-100 micron and smaller range from 6% to 12%. Reducing pressure will reduce drift because larger droplets are formed, but operating nozzles below the recommended pressure will also reduce effective coverage and may result in poor distribution and improper spray overlap. However, nozzle manufacturers have developed nozzles that can be used at pressures as low as 15 psi with little reduction in coverage quality.

Chemical Formulation

A coarser spray can be achieved by increasing the viscosity of the spray mix. Increased viscosity results in an upward shift of the droplet spectrum so that there are fewer of the fine drops that are subject to drift. Many spray additives can be added to a tank mix to increase its viscosity. These products, referred to as drift reducing agents, do not completely eliminate drift, rather they reduce the number of drift-prone droplets. With the increased droplet size from new nozzles, these products may have limited application.

The type of pesticide formulation also plays an important role in reducing drift. Some pesticide formulations are more volatile than others. Therefore, use formulations with low volatility to reduce vapor drift.

Weather

Little control over the weather can be achieved, but its effect on drift can be managed. Wind velocity is usually the most critical factor of all weather conditions affecting drift potential. The greater the wind speed, the farther off-target a droplet of a given size will be carried. The larger the droplet, the less it is affected by the wind and the faster it falls. High winds, however, can cause even larger droplets to move off-target. Therefore, spraying operations should be stopped if wind speed exceeds 10 mph.

Wind direction is as important as wind velocity in reducing the damage caused by drift. The presence of sensitive vegetation near the spray site, particularly downwind, is one of the first things that should be evaluated, but is often overlooked when beginning a spray application. Check in all directions from a spray site for sensitive vegetation, and be alert to changes in wind direction during application. If there is sensitive vegetation downwind, leave a buffer strip of at least 100 feet (300 feet for aerial application) or whatever the label recommends. Spray the buffer strip later, when the wind has shifted away from sensitive crops.

Relative humidity and ambient temperature also directly affect spray drift. While they generally are not as critical as wind velocity, they have strong influences in some geographic regions or under certain meteorological conditions. As a particle falls through the air, surface molecules of water evaporate into the atmosphere. This evaporation reduces the size and mass of the particle, enabling it to remain airborne longer and, under the right conditions, to drift farther from the application site. The rate at which water evaporates from the spray particles depends primarily on the ambient air temperature and relative humidity. Low relative humidity and high temperatures result in higher rates of evaporation.

While evaporative loss of spray materials occurs under almost all atmospheric conditions, these losses are less pronounced under the environmental conditions that occur in the cooler parts of the day: early morning and late afternoon. The relative humidity is usually highest during these cool periods.

Atmospheric stability is another important factor that influences drift. Under standard meteorological conditions, the air temperature decreases by 5.4°F per 1,000 feet of height. Cool air tends to sink, displacing lower warm air and causing vertical mixing. As a warm air layer rises, suspended droplets rise with it and dissipate into the upper layers of air by normal turbulence and vertical mixing. Under these conditions, the opportunity for crop injury at any specific off-target site is very small because the pesticide is dispersed and diluted out into the atmosphere.

On the other hand, when the atmosphere is very stable, other problems may arise. Under very stable conditions, a warm air layer at some distance overhead may become a blanket holding down cooler air underneath. Particles suspended in the cool layer cannot move anywhere except laterally, possibly several miles. Eventually, the suspended
cloud may encounter a down draft forcing it back to earth, depositing it off-target—possibly over a sensitive crop. This phenomenon is usually referred to as atmospheric inversion. Thus, extremely calm conditions can pose a risk for drift; conditions do not necessarily have to be excessively windy.

Inversions are part of a daily atmospheric cycle, occurring in the early morning hours when the ground cools the air layer immediately above it. Inversions tend to dissipate during the middle of the day when wind currents mix the air layers. If concern exists over the presence of these adverse spray conditions, wait until late afternoon or early evening hours to spray, when there is less chance of the atmosphere being inverted, and conditions are more favorable.

The best way to avoid drift associated with atmospheric inversions is to eliminate the formation of small particles (150 microns or smaller) from the spray effluent. Basically, without these particles in the spray emissions, this weather-related phenomenon can be ignored.

**Equipment Modifications**

Spray droplets from conventional sprayers deposit mainly on to upper sides of horizontal surfaces due to gravity, or on vertical surfaces by their velocity and movement in air currents around the target. Researchers and equipment companies have been exploring the possible use of other forces to increase application efficiency while reducing spray drift. Some new developments for increasing deposition efficiency of especially small droplets include partially or completely covered booms, air-assisted spraying, air jet nozzles, and electrostatic spraying.

**Operator Skill and Care**

Under a given spray situation, any one of the above factors may be the most critical in reducing drift hazards. It is the applicator who determines this critical factor and takes precautions against it. By exercising good judgment regarding both equipment and weather factors relative to each application, applicators can minimize drift potential in nearly every case.

Reducing spray drift not only improves application efficiency, but it also reduces the risk of safety and health-related problems caused by drift. Because it is impossible to eliminate drift altogether, always wear protective clothing when applying pesticides.

If you have any doubts about a spraying job that might result in drift, wait until you no longer have that element of doubt. Your goal should be to eliminate off-target movement of pesticides, no matter how small that movement may be. Conscientious and experienced operators rarely get into serious trouble with drift damage because they understand drift and take steps to avoid it.

**Spray Monitors**

Spray monitors (Figure 29-5) may be of two types: nozzle monitors and systems monitors. Nozzle monitors alert the operator to a nozzle problem that may be difficult to observe from the operator’s cab. Plugged nozzles or other problems can be immediately corrected to avoid skips in application.

System monitors detect the operating conditions of the total sprayer. They are sensitive to variations in travel speed, pressure, and flow rate. These values, along with operator input such as swath width and gallons in the tank, are fed to a computer that calculates and displays the travel speed, pressure, and application rate. The monitor also can calculate and display information such as number of acres covered, liquid remaining in tank, estimated acres that can be covered, and field capacity in acres per hour. To function properly, the monitor must have suitable sensors that are accurately and regularly calibrated.

Some monitors also can control the flow rate and pressure automatically to compensate for changes in speed or flow. Flow compensation is usually done by changing the pressure by a throttling valve. If the conditions are such that excessive speed change occurs or a problem in the spray system exists and the controller can not respond, the unit will signal the operator that a problem does exist.

**Direct Injection Metering**

Direct injection sprayers continuously meter concentrated pesticide in the spray system as needed. The system has two or more tanks containing concentrated pesticide and a larger tank used for the carrier, which is usually water. Most units are designed so that the volume metered is
determined by ground speed. Others can vary the metering rate based on a treatment map and the navigation locations or appropriate on-the-go sensors.

The advantage of direct-injection sprayers is that no mixed chemicals are left over when the application is completed. These units also may be used to save pesticides by spot spraying troublesome pests.

One issue with injection sprayers is the timely injection of the pesticide into the system, so it discharges at the proper location. Lead time could vary due to size of the sprayer plumbing, travel speed, spray volume, and location of the injection point. Injection equipment requires precise metering devices and must be maintained and calibrated.

Spray Markers

A marker (Figure 29-6) aids uniform spray application. Markers, such as disk, foam, dyes, line tram, and paper, show the operator where to drive on the next pass to reduce skips and overlaps.

Foam and dye markers are the most popular. Foam is easy to see on dark soil and is not easily blown away on stubble, but it does not last long at high temperatures. Dye lasts a long time and is easily seen on clean wheat stubble and light residue. Some sprayers are equipped with both foam and dye so the operator is prepared for various field conditions.

Markers are a tremendous aid in non-row crops. The mark can be continuous or intermittent. Typically 1 to 2 cups of foam are dropped every 25 feet. Foam or dye requires a separate tank and mix, a pump or compressor, a delivery tube to each end of the boom, and a control switch to select the proper side.

One of the most effective methods of reducing potential skips and overlaps is to double-run. To double-run, mix the spray solution at half strength. During the return pass, half of the previous swath is sprayed again. The return pass is not covered by the same nozzle, so if a nozzle is partially plugged, the area still will be covered with 70 to 80% of the spray solution. This method also allows for excellent visibility of marks because the operator can center the sprayer over the mark on each pass.

Shielded Sprayers

Several drift control methods are available that will reduce spray drift to an acceptable level. A drift control method that is popular in the Northern Plains is spray shields or plastic hoods. In the Plains, wind is almost a constant obstacle to good spraying conditions. So, if wind is blowing on a regular basis, it may be advisable to provide local control of the conditions where pesticides are being applied. Spray shields have shown very good results in reducing off-target movement of...
driftable droplets and in maintaining a uniform band width with the target zone when banding pesticides.

Several manufacturers provide spray shields including full boom shields, individual nozzle shields, and row crop shields. Full boom shields cover all nozzles on the boom either with solid plastic covers or perforated shields. The individual nozzle shields cover each nozzle pattern with an inverted V-shaped shield.

Row crop shields are designed to move between rows, allowing spraying of weeds between the rows. The shields prevent spray from depositing on the growing crop.

Research studies have shown a reduction in spray drift ranging from 50 to 75% when using shields. Shields only reduce drift and do not eliminate all drift. Care must be used when spraying near susceptible crops, as some off-target movement of spray may occur. An awareness of downwind susceptible crops, gardens, and shelter belts must be observed.

**In-tank Rinse Systems**

Regardless of where pesticides are mixed, the amount of rinse water handled at any one location can be reduced by rinsing as much equipment in the field where application occurs. By carrying an auxiliary tank of clean water on the sprayer, the tanks and plumbing components can be washed and rinsed in the field. In-tank rinse systems have nozzles mounted inside the applicator tank. These systems leave the diluted spray material in the field and permit the sprayer to return to the farmstead clean.

**Pesticide Storage and Containment**

Storage, handling, and disposal of pesticides have been identified by state and federal agencies as practices that create high risks to surface and groundwater quality. Details of secondary containment facilities and load pads are discussed in MWPS-37, *Designing Facilities for Pesticide and Fertilizer Containment*. Check with your local regulatory agencies to determine the requirements in your area. Always follow the pesticide label for proper storage, handling, and disposal requirements.

**Site-specific Crop Management (Precision Agriculture)**

The use of site-specific crop management practices will guide the development of new sprayer technology that will enable crop protectants to be applied only to specific regions of a field. This technology could lead to reduced amounts of pesticides applied to fields that are not uniformly covered with pests. The use of variable rate application systems for crop protectants will require accurate information about the spatial distribution of pest populations and a computer-controlled applicator interfaced with a navigation system.

Traditionally, herbicides are broadcast on an entire field without regard to the spatial variability of the weed population in the field. This practice results in areas where no or few weeds exist being sprayed and receiving just as much herbicide as those areas with a high weed population. Information about the distribution of weeds in a field may be gathered using several different approaches.

One method, suitable for postemergence herbicides, is to map the weed distributions as close to the time of application as possible. Geographical Information Systems (GIS) and Global Positioning Systems (GPS) will need to be used to develop application maps for this purpose. Crop scouts, aerial photography, or automated sensing devices also could be used in combination with the GIS/GPS technology to develop the application maps.

Optical sensors can be utilized to distinguish weeds from soil. Currently, it is difficult for these sensors to quickly and accurately distinguish weeds from the growing crop. More complex sensors are being designed, so machine vision can recognize morphological and spectral differences between weeds and the crop.

Obviously, developing sophisticated application delivery systems that could apply pesticides where pests exist and shut off where there are none could reduce pesticide usage or could help place pesticides more effectively. This practice could result in a lower environmental burden and increased agricultural profitability. Selective spraying, spot spraying, or intermittent spraying are different names that are attached to this pesticide application method. Currently, technology is becoming available, making selective spraying a possibility.
Computer technology also can control a new solenoid-activated valve that fits into standard nozzle fittings and can be pulsed on and off at a rapid rate. The flow rate of the nozzle can be varied continuously and independently of pressure and droplet size variations.

Many options exist for the recognition of crop pests for mapping and application use. Currently, insufficient data on spatial distributions of crop pests is available to determine what method may be best. Even less information exists on the economic and environment benefits that could be derived from the adaptation of this technology.

References and Suggested Readings


Quanquin, B.J. 1992. Less drift, more on target with the twin system. ASAE Paper No. 921574, American Society of Agricultural Engineers, St. Joseph, MI, USA.


