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Best Practices for Effective and Efficient Pesticide Application

Erdal Ozkan, Professor and Extension State Specialist, Department of Food, Agricultural and Biological Engineering, The Ohio State University

Applying pesticides requires a high level of skill and knowledge. Increases in the size and complexity of sprayers over the years require even more attention to efficiency, efficacy, and safety. Although each crop requires a slightly different approach to the application of pesticides, some general principles apply to almost all spraying situations. Following these principles will help achieve better control of the problem.

These major principles include:

1. Positive identification of the pest(s)
2. Selecting the pesticide specifically designed to control the identified pest(s)
3. Selecting the proper equipment, particularly the correct type and size of nozzle
4. Applying the pesticide at the right time and under the right conditions
5. Checking the accuracy of equipment (calibration) periodically to ensure the amount recommended on the pesticide label is applied uniformly onto the target

When applying pesticides, certain tasks are required for maximum biological efficacy. These include:

1. Uniform mixing of pesticides (especially dry products) in the sprayer tank. This can be accomplished only if the agitation system in the tank has sufficient capacity for its size and is operating properly.
2. Choosing a pump with sufficient capacity to deliver the required gallonage (gal/acre) to the nozzles
3. Ensuring hoses and fittings between the pump and nozzles are properly sized to minimize pressure losses
4. Ensuring minimum loss of pesticides as they are delivered from the nozzles to the target.
5. Attaining maximum retention of droplets on the target (minimum rebound)
6. Providing thorough and uniform coverage of the target with droplets carrying active ingredients.

Only the most critical issues related to application of pesticides are discussed in this publication. For details of these and other topics, follow the web links to additional educational resources throughout this publication.

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Select the best nozzle type for the job

Although each component of the sprayer plays a role in achieving success in pesticide application, nozzles play the most significant role. Nozzles come in a wide variety of types and sizes. Each type is designed for a specific target and application. Most manufacturers' catalogs and websites have charts showing which nozzle type is best for a specific job. Any of the factors below may be the deciding one when selecting the most appropriate nozzle for the job.

- Sprayer operation parameters: application rate, spray pressure, ground speed
- Type of chemicals applied: herbicide, insecticide, fungicide, fertilizers, growth regulators
- Mode of action of the chemical for spray coverage requirement: systemic or contact
- Application type: broadcast, band, directed, air-assisted
- Risk of spray drift
- Requirements noted on pesticide labels

Choose the appropriate nozzle size

Once you determine the best nozzle that will be best for a specific spraying situation, you need to determine the appropriate size of that nozzle size that provides the application rates (gal / acre) prescribed by product labels under various operating conditions (spray pressures and travel speeds).

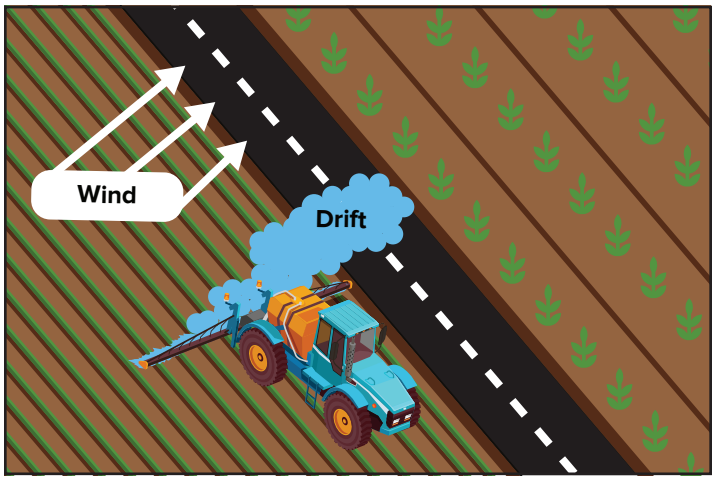
More information on selecting nozzle type and size are outlined in OSU Extension publication FABE-528, "Selecting the Best Nozzle for the Job." (*ohioline.osu.edu/factsheet/fabe-528*)

Keep spray drift in mind when selecting nozzles

Although complete elimination of spray drift is impossible, problems can be significantly reduced by awareness of the major factors that cause drift, while taking precautions to minimize their influence on off-target movement of droplets.

Follow these tips to minimize spray drift:

Eskil Nilsson; Visavi, Sweden



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1. Nozzles play a significant role in generating as well as reducing spray drift. ASABE (American Society of Agricultural and Biological Engineers) developed a standard used by nozzle manufacturers to classify nozzles based on droplet size (spray quality) produced from nozzles at different spray pressures. Spray quality classes include: Extremely Fine, Very Fine, Fine, Medium, Coarse, Very Coarse, Extremely Coarse, and Ultra Coarse. Most nozzles used in agriculture produce droplets ranging from Fine to Very Coarse. Research clearly indicates nozzles producing spray qualities

of Coarse or coarser significantly reduce spray drift, as discussed in OSU Extension publication FABE-523 "Effectiveness of Turbodrop® and Turbo TeeJet® Nozzles in Drift Reduction." (*ohioline.osu.edu/factsheet/fabe-523*). However, if drift is not a concern, and the pesticides applied require maximum surface coverage of the target plant, using nozzles producing Medium spray quality will most likely provide better efficacy.

2. Keep nozzles as close to the target as possible while still producing a uniform distribution of spray on the target.
3. Consider using a sprayer equipped with air-assist technology on the spray boom. When used under fully or partially developed crop conditions, air flow coming out of the boom just behind the nozzles carries the small, drift-prone droplets into the canopy where they can be deposited.
4. Drift retardant chemicals designed to increase droplet size, and reduce the number of very small droplets can be added to the spray mixture. This option, however, should be the last defense against drift. Always consider other options, such as better targeting the spray and switching to low-drift nozzles.
5. If weather conditions (wind speed and direction, humidity, temperature, inversions) are not favorable, and there is concern about spray that might result in drift, wait until there is no longer that element of doubt. Review the forecast and schedule spraying accordingly. Use APPs that provide current, local wind conditions and estimate periods of time to spray or not to spray.

Extensive information related to factors influencing spray drift, is in OSU Extension publication FABE-525. "Effect of Major Variables on Drift Distances of Spray Droplets." (*ohioline.osu.edu/factsheet/fabe-525*).

Maximize pesticide deposit and coverage on the target

To achieve effective pest control, choose the nozzle and set up the application equipment based on what is being controlled and the part of the plant canopy that is being targeted. For example, when applying a fungicide to manage Fusarium head blight or "head scab," on small grains, the target is the head, not the leaves. When a fungicide is applied using nozzles that direct the spray downward, most of the product is deposited on the leaves or the ground and not on the head. However, when trying to control diseases such as soybean rust, the target should be the leaves, especially ones in the lower part of the canopy. When spraying for soybean white mold, the most critical area that needs to be treated with fungicides is where flowering takes place. Nozzle selection has a significant influence on whether or not the droplets reach the specific target location in the canopy.

The following trends have emerged from two multi-year Ohio State studies on target deposition for diseases on soybeans and wheat:

- Nozzles and equipment setups that define droplet size as "medium" (approximately 250-350 micron diameter droplets), provide better penetration of droplets into lower parts of the canopy versus nozzles producing smaller or larger droplets. These are appropriate for both wheat and soybean canopies to control rust in wheat, and aphids and stem rot in soybeans. Stem rot usually starts from the lower part of the canopy, requiring treatment of that region with fungicides as early as possible.
- Compared to hollow cone nozzles, single pattern flat-fan nozzles producing medium size class droplets provide better penetration inside the soybean canopy when the canopy is dense.
- Spray deposition hitting the target from two different angles using nozzles producing twin spray patterns, such as a TwinJet, produces better coverage and deposition on upper parts of the soybean canopy. It can produce acceptable control of diseases in the lower part of the canopy if the canopy is not too dense. In dense soybean canopy conditions, twin pattern application provided the lowest coverage and deposits on lower parts of the canopy. Twin pattern nozzles or a single flat-fan nozzle tilted at a forward angle of 30 to 45 degrees down from the horizontal reference is definitely best for the application of fungicides for wheat head scab. It is, however, the worst setup for soybean insects and diseases, such as aphids and Sclerotinia stem rot (white mold).

Erdal Ozkan, The Ohio State University

Calibrate the sprayer

A sprayer can only be effective, efficient, and safe if properly checked and calibrated well before the sprayer is taken to the field, and periodically during the spraying season. Some may argue that most sprayers are now equipped with sophisticated rate controllers and ground speed sensors, and calibration is not necessary. Unfortunately, not all electronic controllers can detect flow rate changes on each nozzle on the boom, and none can detect changes

in spray pattern. If the ground speed sensor works based on revolutions of the tractor wheels, the ground speed determined may not be accurate, because of the slippage that may occur under some ground conditions. Manual calibration is always good to ensure the electronic controllers and sensors are working properly.

The primary goal with calibration is to determine the actual rate of application in gallons per acre, and then make adjustments if the difference between the actual rate and the intended rate is greater or less than 5% of the intended rate. Although rate controllers can regulate the flow rate of nozzles to keep the application rate constant, a manual calibration at least once a year is needed to ensure the rate controller is functioning properly.

Before starting calibration, make sure the sprayer has a good set of nozzles. Nozzles wear through extended use, causing over-application and/or non-uniform application. Some nozzles or screens may become clogged causing under-application. Clean all clogged nozzles and screens. Check the output of all the nozzles for a given length of time at a given spray pressure. Compare the output from each nozzle with the expected output shown in the manufacturers' catalog for the selected nozzle at the same operating pressure. Replace any nozzles showing an output error of more than 10% of that recommended for a new nozzle by the manufacturer.

- Calibrating a sprayer involves taking three specific measurements: 1) actual ground speed, 2) the distance between nozzles, and 3) nozzle flow rate for a given length of time
- Just three things are needed to take these measurements: 1) a timer showing seconds, 2) a measuring tape, and 3) a measuring cup graduated in ounces
- A mixture containing pesticides may have a slightly higher density or viscosity, which may slightly change the flow rates of nozzles. Usually the difference in flow rates between water alone and a mixture containing pesticides is not significant, unless liquid fertilizer is the carrier. For safety reasons, use water only in the tank when calibrating sprayers. Conversions for spray solutions with different densities are provided in the manufacturers' catalogs if a carrier other than water alone is used during calibration.
- Even when using water alone when calibrating the sprayer, always wear personal protective equipment such as gloves and goggles as when spraying pesticides.

There are several ways to calibrate a sprayer. One easy method, the 1/128th method, is explained in the OSU Extension publication FABE-520, "Calibrating Boom Sprayers." (*ohioline.osu.edu/factsheet/fabe-520*).

Erdal Ozkan, The Ohio State University

Understand how to calculate the amount of chemical product to mix in the tank

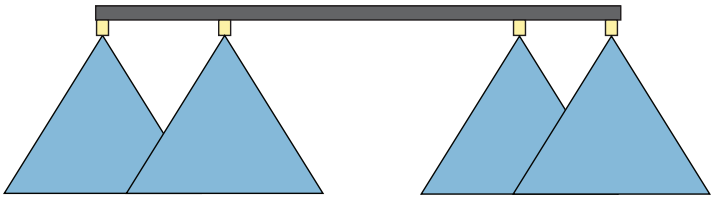
Although your sprayer may be in good condition and calibrated frequently, if the correct amount of chemical is not put into the tank, it can still result in unsatisfactory pest control. Labels list two recommended application rates: volume of spray mixture (pesticide and water) applied per unit area (gallons per acre, ounces per 1,000 square feet, etc.), and the amount of actual chemical applied per unit area (ounces, pints, or quarts per acre or 1,000 square feet). The first recommendation (volume of spray per unit area) is attained through proper calibration and operation of the sprayer. The second label recommendation requires not only proper calibration and operation, but also the right concentration of the actual product applied.

The amount of chemical needed per tankful depends on the recommended rate and the size of area that can be treated per tankful of spray. Calculations and concepts are the same whether using a manual backpack sprayer with a five-gallon tank, a lawn mower/ATV sprayer with a 15-gallon tank, a pull-type sprayer with a 500-gallon tank, or a 1,500-gallon self-propelled sprayer. The only difference is in units. For small sprayers, the rate may be expressed in ounces, quarts, or gallons per 1,000 square feet. For boom sprayers, the application rate is usually given in gallons per acre (gpa). Detailed information on how to calculate the proper amount of chemical to add to the spray tank is provided in the OSU Extension publication FABE-530. "How Much Chemical Product Do I Need to Add to my Sprayer Tank." (*ohioline.osu.edu/factsheet/fabe-530*)

Check uniformity of application

How the chemical is deposited is as important as the amount applied. Maintain uniform deposition of spray material on across the entire width of the target area. Non-uniform coverage results from using misaligned or clogged nozzles, using nozzles with different fan angles, or from uneven nozzle height across the boom. These common problems result in streaks, untreated areas, or over-application of

FLAT-FAN NOZZLES USED FOR BROADCAST SPRAYING REQUIRE 30–50% OVERLAP OF ADJACENT SPRAY PATTERNS.



30% overlap 50% overlap

chemicals. Nozzles which produce uniform or "even" distribution of spray across the spray pattern (no tapering of spray closer to the edges of spray pattern) should be used when spraying products directly on targets, such as young vegetable seedlings in a narrow band for insecticide application, or the area between rows of vegetables for weed control. With these types of nozzles, no overlapping of spray patterns are required since the product is evenly distributed across the spray pattern. However, when making broadcast applications covering the entire area under the boom, the regular flat-fan nozzles should be used. These flat-fan broadcast nozzles produce spray patterns with heavy spray volume discharged from the center of the spray, and the volume tapers off towards both end of the triangular-shaped spray pattern. When using such flat-fan broadcast nozzles, spray patterns from adjacent nozzles must overlap to obtain uniform coverage across the spray swath, as shown in the figure above. A low boom or a boom set too high creates a poor pattern and misapplication. Check the nozzle catalog to determine the proper boom height recommended for different nozzle types and spacings.

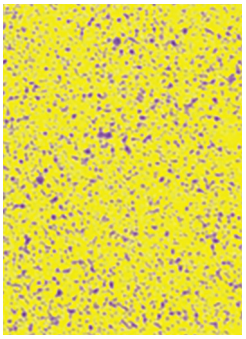
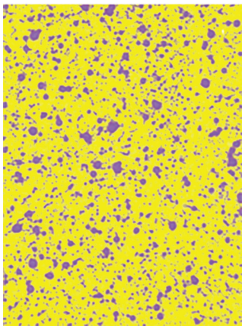
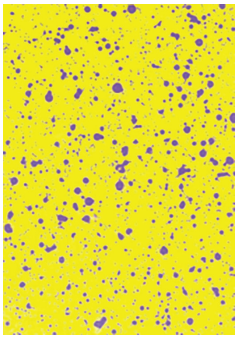
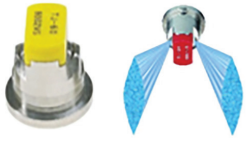
Make sure the nozzles are not fully or partially clogged. Clogging not only changes the flow rate, but also the spray pattern. Do not use a pin, knife or other metal object to unclog nozzles. This damages the nozzle orifice, causing changes in the flow rate and distortions such as streaks in the spray patterns. Use a soft brush, or pressured air to unclog nozzles. In addition to clogging, mismatched nozzle tips on the boom and uneven boom height are the most common causes of non-uniform spray patterns. They can all cause streaks or untreated areas that result in insufficient pest control and economic loss.

Read product label for specific recommendations and requirements

Most product labels outline some vague and general statements when referring to the application of products, such as "use nozzles that provide thorough coverage of the canopy." There is no explanation about what "thorough coverage" represents or how to achieve it. It is your job to select a nozzle and operate it under certain pressure conditions to achieve "thorough coverage." Some labels give specific recommendations on nozzles such as: "use nozzles that provide medium spray quality" or "do not use nozzles that produce droplets in coarse or larger spray qualities." When there is this kind of specific information on the label, in addition to satisfying the gallon per acre requirement, also satisfy the droplet size requirement. Under these conditions, the operator's job is to choose a nozzle type and size that satisfies the required droplet size while meeting other requirements such as gallons per acre application rate. For example, the nozzles shown in the figure below all produce the same flow rate (0.2 gallons per

EFFECTS OF NOZZLE TYPE ON COVERAGE

(Flow rate: 0.20 gpm)

	Twinjet 11002	XR 8002	TurboTeejet 11002	Air Induction 110015
Spray Coverage				
Pressure	**40 psi**	**40psi**	**40psi**	**70psi**
Nozzle				
Droplet Size Class	**Very Fine**	**Fine**	**Medium**	**Coarse**

minute) at the same or slightly different pressures, but each provides a different spray quality (droplet size). Check the information given in nozzle manufacturers' catalogs to make sure the nozzle provides the required spray volume at a given travel speed and spray pressure, as well as the spray quality (droplet size) under these same operating conditions.

Typically, systemic products do not require thorough coverage of the target, so coverage is not a significant issue when spraying them. However, contact-type products work best when applied evenly on the surface and coverage is maximized.

There are two options to improve coverage: 1) Increase the pressure. Higher pressures lead to creation of smaller droplets which provide improved coverage. 2) Increase spray application rate (gal/acre). When satisfying label requirements or recommendations related to coverage, in addition to the type and size of nozzle used, the rates of application can also help achieve higher levels of coverage. As shown in the following figure, regardless of the spray quality (droplet size) class, increasing the spray application rate increases product coverage.

Keep in mind that an increase in spray pressure always results in an increase in the spray volume contained in smaller droplets. This most likely results in higher levels of spray drift, especially when using conventional flat-fan or cone nozzles with smaller orifice sizes. Relying on increased pressure to improve spray coverage should be the last option, practiced only when the weather conditions are not conducive to increasing spray drift. The first option to improve spray coverage should be to select the right type and size of nozzles, followed by the next option, increasing the spray application rate.

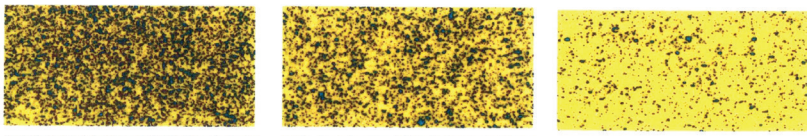
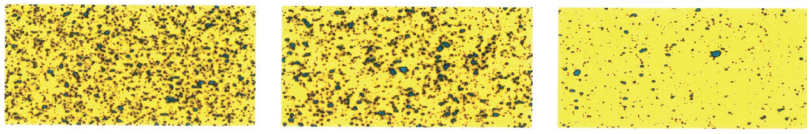
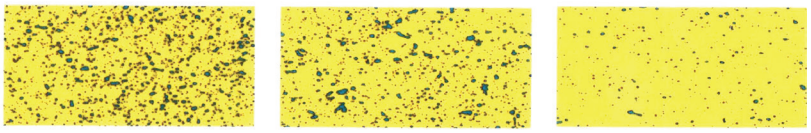
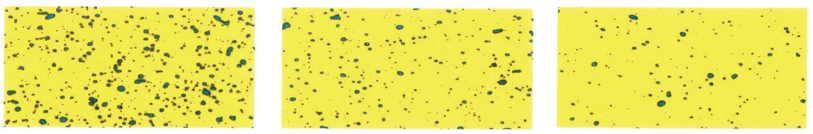
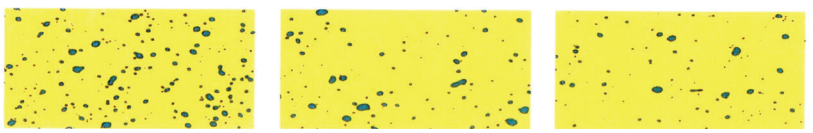
Give special attention to selection of nozzles when applying pesticides containing 2,4-D and Dicamba

The labels of 2,4-D or Dicamba herbicides include specific requirements for nozzles and operating pressure ranges. These strict requirements are put on the labels to eliminate off-target movement or drift of spray droplets. If you use any other type and size of nozzle and operate them outside the pressure range requirements given by the pesticide manufacturers, you are violating the pesticide label, and therefore the law. Remember, the label is the law!

It is your responsibility to comply with the requirements on pesticide labels. A list of currently approved nozzles and the operating pressure ranges on labels of several commonly used 2,4-D and Dicamba products can be found at: *pested.osu.edu/sites/pested/files/imce/ApprovedNozzles.pdf*

The table at this site is provided for information purposes and may not be up-to-date. Check the manufacturers' websites and read the product labels for the most current information. Do not assume you do not have to worry about checking the label, because the same product was applied in a previous year. A nozzle required for the same product last year may not be on the label this year, or the operating

APPLICATION RATE AFFECTS SPRAY COVERAGE

	Application Rate		
Droplet Size	**12 gpa**	**8 gpa**	**4 gpa**
Fine			
Medium			
Coarse			
Very Coarse			
Extra Coarse			

Tom Wolf, sprayers101.com

Keep in mind that an increase in spray pressure always results in an increase in the spray volume contained in smaller droplets. This most likely results in higher levels of spray drift, especially when using conventional flat-fan or cone nozzles with smaller orifice sizes.

pressures might have changed.

Take advantage of technological advancements in spray technology

A rate controller on a sprayer was one of the most significant developments more than four decades ago. These gadgets enabled sprayer operators to keep the application rate constant, regardless of changes in ground speed. They are now a standard component of every new sprayer sold. No other significant developments occurred in spray technology for a couple of decades until auto steering/ guidance of tractors or self-propelled sprayers, and Global Positioning System (GPS) technology entered in how we operate farm equipment.

Until the arrival of the auto guidance technology, sprayer operators relied on using either foam markers or other mechanical means to mark the edge of each spray pass and avoid excessive overlaps. Neither approach was reliable, especially when using sprayers with wide booms and driving long distances in the field before turning back for the next spray swath. Under these conditions, the markings could be undetectable, especially with foam markings and when operator fatigue becomes an issue. When making multiple back-and-forth passes in the field, using auto guidance technology enables precise positioning of the sprayer, resulting in minimum overlap between each pass.

An extension of this technological development is the automatic on-off of nozzles, as a group on various sections of the sprayer boom, depending on the pre-programmed spray map using GPS data for the field sprayed. For example, when approaching grass waterways, a section of the boom intersecting the grass waterway can be turned off automatically until that section is clear off the waterway. This technology evolved into independent control of each nozzle on the sprayer boom regardless of where it is located.

Independent control of nozzles may not be important if the spray pass is always on a straight path, clear of obstacles. However, every pass includes a turn at the end and the sprayer may be following contours during spraying. Under these spraying conditions, the travel speed of nozzles located towards the ends of the boom are much faster than the nozzles close to the tractor and center of the boom. With conventional control systems, this leads to under application of chemicals on the ground under the nozzles towards the outer edges of the boom, while the ground near the center of the boom receives a higher dose of chemicals. This inaccuracy can be avoided using the individual nozzle flow control technology, usually referred to as the pulse width modulation (PWM). It is available on new sprayers manufactured by several companies and can be retrofitted on other sprayers lacking this technology. In addition to providing individual flow rate control at each nozzle, the PWM technology also allows the sprayer operator to keep the droplet size constant, regardless of changes in spray pressure. This is a major drawback of the conventional rate controllers without PWM technology. With conventional rate controllers, when the ground speed of the sprayer goes up, the system pressure goes up to maintain the constant gal/acre application rate . When pressure increases, size of droplets discharged from the nozzle decreases. Detailed information on how this technology works is provided in a Kansas State University publication available online (*bookstore.ksre.ksu.edu/pubs/MF3314.pdf*). Additional resources can be found on the web by searching for “pulse width modulation spraying.”

One other significant technological development available for integration into sprayers is sonar sensors on the boom that keep the boom sections retain the desired boom height. As cited earlier, spray coverage on the target is not uniform if the boom height deviates from the optimum recommended height. It is highly recommended that sprayers with large booms are equipped with sonar sensors to keep all sections of the sprayer boom at the same height during spraying.

Final thoughts

The information presented in this fact sheet will help achieve better performances from applied pesticides. However, only the most significant issues are highlighted in this publication. For detailed coverage of these and other topics, visit the web sites of the resources listed throughout the publication. There are equally important topics not covered in this publication, including: general inspection of the sprayer, importance of proper product agitation in the sprayer tank, adequate size hoses and fittings, determining sprayer setup for acceptable application rate, selecting proper boom height based on nozzle angle and spray overlap, compatibility of products mixed, cleanliness and pH of water used to mix the products in the tank, proper cleaning of the sprayer tank, spray additives that can enhance product performance, and handling pesticide waste and empty containers. Detailed information on these and other topics not included in this fact sheet can be found in OSU Extension publication FABE-527, “Best Management Practices for Boom Spraying.” (*ohioline.osu.edu/factsheet/fabe-527*). Another excellent source of information on a wide range of topics related to pesticide application technology is *sprayers101.com*.

Acknowledgment

The author thanks Dr. John Fulton and Dr. Ajay Shah, Professors at Department of Food, Agricultural and Biological Engineering, The Ohio State University; and Mary Griffith, Agriculture and Natural Resources Extension Educator, Ohio State University Extension, for reviewing this publication and for their editorial contributions.

Following is a summary of recommendations discussed in this publication:

- Carefully read and follow the specific recommendations provided on the pesticide label, in nozzle manufacturers' catalogs, and sprayer operator's manuals.
- Calibrate the sprayer to ensure the amount recommended on the label is applied.
- Check the sprayer setup to ensure the amount applied is distributed evenly across the spray swath.
- If more than one type of chemical is added to the sprayer tank, check product labels to ensure mixing is done in the appropriate order.
- Conduct calibration of sprayer, mixing and loading of chemicals in areas without risk of ground/surface water pollution.
- Operate the nozzles at a pressure that allows them to produce the spray quality (droplet size) recommended on the product label.
- To achieve best coverage on the target, select the appropriate nozzles for the product, and if applicable (not restricted by the label) keep the spray volume (carrier application rate) above 15 gpa for ground and 5 gpa for aerial applications.
- Slow down when spraying. Spray coverage is usually improved at slower speeds. The higher the travel speed, the greater likelihood of spray drift.
- Probability of spray drift is much greater with fine to medium droplets than with coarser droplets.
- For herbicide applications, flat-fan nozzles are better than cone nozzles which tend to produce a much smaller proportion of extremely small, drift-prone droplets.
- Good coverage of just the top of the canopy may be sufficient for adequate pest control with some products. However, both horizontal and vertical coverage of the plant may be necessary for other situations, such as disease and insects that may be hidden in lower parts of canopies.
- Air-assisted sprayers usually provide better coverage and droplet penetration into the canopy, than conventional sprayers when there is a full, dense canopy, such as soybeans sprayed in late season.
- Be careful when using twin nozzle/pattern technology for application of fungicides. Two nozzles or spray patterns angled (one forward, one backward), work better when the canopy is not dense and tall, or when the target is the upper part of the canopy, such as with wheat head scab. Use single flow pattern nozzles under dense canopy conditions when penetration of droplets into the lower parts of the spray canopy is desired.
- Be safe. Wear protective clothing, goggles and rubber gloves, and respirators if required on the label, when calibrating the sprayer, doing the actual spraying, and cleaning the equipment.

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