2. APPLICATION TECHNOLOGY

Introduction
Herbicide application should be a precision operation. Recent advances in equipment and control systems can make the job relatively simple and precise.

Pesticides applied incorrectly may result in wasted pesticide, poor or no control, damage to crops (possibly the neighbour’s) or environmental contamination. Every effort must be made to apply chemicals properly.

Developments in New Equipment
In building sprayers that accurately apply herbicides, equipment manufacturers work closely with the crop-protection industry. Innovations, such as closed-injection systems with herbicide concentrate carried separately from the water carrier, are now in use. Electronic rate controllers provide more accurate spray application by utilizing speed sensors, flow controllers and microprocessors to maintain the desired application rate. This technology has also included radar to accurately sense true ground speed of the sprayer. Rate controllers are commonly used by professional applicators. GPS guidance control systems with possible auto steer allow sprayers to cover the field with minimal overlap swath to swath. This allows for complete field spray coverage while not double applying product in certain areas.

The industry is currently working towards the closed-injection system. Work continues in the area of drift reduction using air assist and electrostatic spray methods.

Air-induction nozzles significantly reduce spray drift and are available in a range of sizes from a number of suppliers. Operating these nozzles within their working pressure range is crucial to ensure designed spray angle development, proper air induction into the nozzle and necessary droplet size for the job at hand. Before buying air induction spray tips, make sure your sprayer pump can produce sufficient pressure to operate these tips under all conditions. Check with the nozzle manufacturers for operating pressures required. Most nozzle manufactures a variety of air induction nozzles including both low-pressure and high pressure designs.

Field Sprayers
The most common type of sprayer used in herbicide application is the boom sprayer. This sprayer applies a uniform amount of spray solution across the width of the boom.

The main requirements for field spraying are:

- uniform pressure across the whole boom
- all nozzles have the same output and a good spray pattern
- a constant forward speed in actual field conditions
- ability to adjust boom height so that the required nozzle – to – target height can be achieved
- a stable boom height to ensure proper overlap of the nozzle-tip patterns

Most commercially built sprayers can be adapted and used safely to apply liquid fertilizers. Extra agitation may be required. Ensure that the sprayer components being used will resist the corrosive nature of some fertilizer formulations and follow the manufacturer’s recommendations.

Air-Blast or Mist Sprayers
These machines should never be used to apply herbicides, especially hormone-type herbicides such as 2,4-D. The danger of causing off-target crop injury at a great distance from the treated area is very high.

Wiper Applicators for Selective Weed Control
Wiper applicators (rope-wick, roller applicator or similar devices) containing glyphosate can be used when the target weeds are taller than the crop so as to avoid contact with a crop sensitive to that herbicide. Other products may exist that can be wick applied. Refer to intended product labels for use of this application technique. The main criteria for using wiper applicators are:

- contact enough of the target plant to get herbicidal effectiveness
- keep the wick application above the crop to avoid crop injury

Travel speeds should be 4–10 km/h for wick application. Two passes in opposite directions may be beneficial, especially in heavy weed infestations and where higher vehicle speed is contemplated. Care must be taken not to contact sucker growth in orchards, vineyards and shelterbelts. This may result in crop injury.
Care and Use of Equipment

Spraying Speeds

Since herbicides must be uniformly applied, the forward speed of a sprayer must be constant whenever the nozzles are delivering liquid. If the driving wheels of a tractor slip on the soil surface, the tractor's speedometer does not indicate a change in forward speed. To be certain that the forward speed is constant in spite of wheel slippage on hills, or loose soil, use an independent speedometer powered by a non-driven wheel or use newer radar or GPS speed sensors. Spray monitors and other electronic rate controllers also may be installed. Only rate controllers will automatically adjust for variation in tractor speed to maintain a constant rate of application.

Water

Use only clean water that contains no debris, soil or organic matter. On your farm water supply, use a frost-free water hydrant located outside a building. An anti-backflow or anti-siphon valve should always be installed on any hydrant or water supply. Never allow the suction screen to rest on the bottom of a farm pond while filling a sprayer. The intake line near the screen must, by law, be equipped with a spring-loaded check valve or anti-backflow device to prevent contamination of the pond or stream when the pump is shut off. Tank-refilling nozzles, volume-booster nozzle or injection pumps should not be used to refill the sprayer tank from farm ponds or streams. These tank-refilling aids may cause pond or stream contamination.

Agitation

When chemical formulations in solution are used (e.g., 2,4-D and water) at least 2–14 L of spray solution should be returned to the tank each minute to provide adequate agitation. Higher rates will apply with wettable powders or flowable formulations, choose a pump with an abrasion resistant housing. Carefully follow the manufacturer’s care and storage instructions for the best pump performance.

When wettable powder herbicides are used, the return to the tank should be 14–27 L/min for each 450 L of tank capacity. A dedicated line from the pressure side of the pump (not the pressure regulator) to the tank must be used to supply the liquid necessary for hydraulic agitation in the tank. Always use a venturi jet or sparge tube. This flow can be reduced if the sprayer has a mechanical agitator. Sparge tube agitation requires more water than venturi nozzles to give the same agitation.

Avoid excessive agitation of the mixture, as it may turn into an invert immulsion, a grease-like mass that will settle to the bottom of the tank and cannot be pumped. Excessive agitation may also cause foaming resulting in pumping problems. To prevent a build-up of oil in the sprayer, the tank should be emptied completely before refilling. After any break in the spraying operation, agitate thoroughly before resuming operation. Immediately after use, clean the tank and sprayer with a detergent or solvent and flush with clean water.

Pumps

The pump is the most important part of the sprayer and should have adequate capacity to maintain the desired pressure, volume and agitation. Piston, diaphragm and centrifugal pumps are best for pumping wettable-powder suspensions. For liquid herbicide applications, roller pumps may be used in addition to the above types. When used for wettable powders or flowable formulations, choose a pump with an abrasion resistant housing. Carefully follow the manufacturer’s care and storage instructions for the best pump performance.

CAUTION: Running a spray pump without water may cause damage or premature wear.

Nozzle Tips

Numerous companies make spray nozzles. Nozzles from different suppliers may be similar in design but may differ in setup requirements. Always follow manufacturer’s recommendations for nozzle spacing and nozzle-to-target distances. These distances may vary according to the spray angle of the nozzle. Proper spacing and orientation of nozzles is essential to ensure adequate overlap of adjacent nozzle spray plumes.

Care should be taken to maintain a stable boom height to ensure uniform overlap of the nozzle spray patterns.

The success of the spray application is dependent in part on the condition of the nozzle tips and the uniformity of application across the whole spray boom. The spray pattern of all nozzles should be examined prior to their use. In addition, every nozzle should be checked when calibrating the sprayer.

Materials used for nozzle tips range from brass, stainless steel, hardened stainless steel, as well as plastics/polymers and ceramics. All product formulations and carriers cause wear of the nozzle orifice. Wettable powders cause abrasive wear, more than other formulations.

Sprayers should be calibrated regularly. (See Care and Use of Equipment, “Sprayer Calibration”).

Nozzle tips should be replaced when they deliver 10% more than manufacturer’s rated output specifications or when their distribution pattern becomes unacceptable.

Flat fan nozzles are widely used on boom sprayers to apply herbicides. Spray operating pressures should be within limits specified by the nozzle manufacturer. Nozzles with a 110 degree spray angle have more overlap than 80 degree nozzles. This allows less chance of spray skips as the boom moves closer to the ground. Always follow manufacturer’s recommendations for spacing minimum nozzle to target distance and spray operating pressures.
Air induction or venturi nozzles are now available from at least a dozen different suppliers. These nozzles were specifically designed to reduce the amount of fine droplets produced in the smaller nozzle sizes. The nozzle manufacturers offer air induction or venturi nozzles in a wide range of sizes.

These nozzles draw air into the nozzle as the spray liquid passes through the nozzle venturi. The result is a coarser spray with very few fine spray droplets that are prone to drift. These coarse droplets contain air bubbles that cause the droplets to rupture upon impact with plant surfaces.

Air induction nozzles are made in two pressure ranges, low pressure and high pressure. If a sprayer cannot exceed 345 kPa, only consider a low pressure design. All venturi nozzles should be operated in the middle of their working range. For the low pressure designs this is approximately 275 kPa and in the high pressure designs, about 550 kPa. All venturi nozzle designs are extremely sensitive to low working pressure. The spray patterns will collapse to less than their designed spray angle if the nozzle pressure is too low. In addition, the induction of air into the spray liquid will not occur if the pressure goes below the operating range of the nozzle.

Many producers have quickly adopted this new nozzle technology. The significant reduction in spray drift, compared to conventional flat fan nozzles, is a welcome feature. See Figure 2–1. Conventional vs. Air Induction Nozzles, on this page. Some producers are using these nozzles for all their herbicide spraying.

Some product performance problems have occurred when air induction or venturi nozzles have been used. Poor timing of spray, reduced water volumes, spray pressures that are too low and difficult-to-wet weeds may all contribute to poor control.

Special “even flat fan” spray nozzles are available for band spraying of herbicides. These even flat fan nozzles deliver a uniform amount of spray over their sprayed area. A variety of sizes, spray angles and nozzle materials are available. The nozzle-to-target height, and spray angle of the nozzles as well as their orientation to the direction of travel, determines the width of the sprayed band. Carefully follow the manufacturer’s literature and directions.

Flooding nozzle tips are used at low pressures and, because of their wide spray angle, can be used closer to the ground surface, thus reducing the potential for drift. New flooding nozzle tip designs have improved the spray distribution patterns to the point that it is as good as with the flat fan tips. Flooding nozzle tips are available in brass, plastic/polymers and stainless steel. Half as many of these nozzle tips are required to cover the same width as would be required with flat fan nozzles.

Full or hollow cone nozzle tips may be used for applying herbicides to the soil surface when the herbicide is mixed into the soil with a disk harrow, cultivator or similar tillage implement.

NOTE: When using any nozzle for spraying wettable powders or micro-nutrients, it is essential to calibrate the sprayer frequently because, as a nozzle wears, the quantity of spray material delivered increases and distribution is uneven. Worn nozzles usually result in a poor spray pattern.
Nozzle manufacturer’s catalogues will list screens required for various nozzle types and sizes. Diaphragm check valve nozzle bodies will ensure dripless operation when the boom is turned off. To clean nozzle screens, remove them from the nozzle bodies and wash thoroughly with soap and water, using a nozzle tip brush. Simply flushing water through the boom and nozzles will not remove pesticide residue that has built up on the outside of the nozzle screens.

**Tank-mixing**

When it comes to reliable information on tank mixing, there are many resources available. The label is, of course, your first point of reference. You can also consult a trusted point-of-sale or agrichemical representative: they know their products best and want to see you succeed. If you are considering a new tank mix, it’s best not to exceed three tank partners. The more you put in, the more likely active ingredients and formulated adjuvants will be incompatible.

“Compatibility” in this case means that mixing products will not cause a chemical problem (e.g., affect product efficacy) or a physical problem (e.g., products gel or fall out of suspension). In Canada, users of commercial class pest control products for crop protection or vegetation management are permitted to apply unlabeled tank mixes of registered pest control products as long as:

- Each partner is registered for use on the crop.
- The tank mix only includes an adjuvant when specifically required by one of the mix partners.
- The application timing of each partner is compatible with crop and pest staging.
- Each partner is used according to the product label.
- No partner is specifically excluded on any other partner label.

**Cleaning the Sprayer**

Before cleaning the sprayer, dispose of surplus tank mix. As suggested in the Grower Pesticide Safety Course, one method of disposal is to dilute the remaining spray solution at least 10:1 with water. This diluted solution can be applied to the previously treated area as long as the maximum labelled product rate is not exceeded.

Clean out the sprayer immediately after finishing the day’s work or when changing chemicals. At the end of each spray day, thoroughly flush out the boom with plenty of water to rinse lines, diaphragm check valves and nozzles. Delaying clean out, even overnight, can allow the formation of hard-to-remove deposits. The sprayer tank is much more difficult to clean out, if it is allowed to dry. Don’t forget to also clean out the measuring containers.

**Steps**

1. Read the product label to determine the recommended cleaning procedure. Have all the materials required for the cleanup ready, including appropriate personal safety equipment.
2. Drain the spray tank.
3. Fill the tank with water and add detergent, ammonia or other tank cleaner product and agitate for 10–20 minutes (clean the whole tank not just the bottom half). Flush boom and hoses with solution, allow to stand for several hours (or overnight if possible) and then flush boom and nozzles again and drain the tank. When flushing the boom, open the boom ends to get particles out of the boom.
4. Inspect the inside of the tank for visual residues. Rinse the inside of the tank if necessary. Repeat step 2.
5. Wash the outside of the sprayer with soap or mild detergent and water.
6. Remove nozzles, screens, and wash separately in a bucket containing cleaning solution. Wash out measuring containers with the cleaning solution.
7. Remove all boom end plugs or caps. Product residues collected in the ends of the various boom pipe sections could cause crop injury. Thoroughly clean out the plugs or caps and pipe ends with cleaning solution. Carefully replace all the boom end plugs or caps.

Thoroughly rinse the tank, hoses, booms, nozzles and screens with clean water for a minimum of 10 minutes. Repeat immediately before the next use.

Use household detergent at rate of 250 mL/100 L or 1 kg/150 L of water. Use ammonia (3%) at 1 L/100 L of water. Use other cleaning agents according to label directions. Never mix ammonia with chlorine bleach. Chlorine gas is produced which may cause severe eye, nose, throat, or lung irritation.

**NOTE:** Contact the manufacturer of pesticides being used to determine the best methods and product(s) to clean residue from tanks and associated equipment. Read the label, since many products provide specific tank-cleaning information on their label.

When surfactants or fertilizer solutions (e.g., AGRAL 90, 28% UAN) are used in a labelled mix with herbicides, there may be some inadvertent cleaning of previous residues from the tank/equipment that could affect the crop. Proper cleanout when changing products is essential to prevent crop injury.

The wash water contains herbicide. Never allow wash water to run into a well, lake, pond, river or other water source.

Do not leave puddles of herbicide solution, tank cleaning or rinse water that may be accessible to children, pets, farm animals or wildlife.
Sprayer Calibration

Field Boom-Type Sprayer Calibration

(Determining application rates in L/ha).

There are many ways of determining the rate of spray material that is being applied to 1 ha of land.

Instructions

1. Measure the time.
   - Place 2 stakes 50 m apart in the field.
   - Select the gear and throttle setting (rpm) at which you plan to spray. Half-fill the sprayer with water.
   - Drive the distance between the stakes three times, timing each pass. Each time, make sure the tractor is at the desired speed as you pass the first stake. Continue driving at this speed until you pass the second stake.
   - Note the average time of the 3 passes.

2. Measure the average nozzle output.
   - Park the sprayer with the PTO engaged and the throttle adjusted to reach the PTO speed set in the test run.
   - Adjust the pressure regulator to the desired working pressure with full flow to the boom.
   - Collect the output from each nozzle for the average length of time needed to travel the 50 m in the test run.
   - Enter the nozzle outputs into the equation below.
     If any nozzle is more than 10% above or below the average output, it should be cleaned, re-tested and if still 10% off, be replaced.

3. Measure the nozzle spacing in metres.

4. Use the following formula to determine the sprayer output:
   \[
   \text{Sprayer Output} = \frac{\text{Average Nozzle Output (mL)}}{\text{Nozzle spacing (metres)}} \times 0.2
   \]

5. Calculate the area sprayed per full tank of spray solution. Re-check the sprayer calibration after each tank of spray is applied by dividing the volume sprayed by the area sprayed. The nature of some products may slightly alter the calibration from that of clean water.

6. Growers who are more comfortable with litres/acre or gallons/acre can use the following conversion guide.
   - Litres/hectare × 0.4 = L/acre
   - Litres/hectare × 0.09 = Imp. gal/acre
   - Litres/hectare × 0.11 = U.S. gal/acre

Sample Calculation

Average time to travel 50 m (164 ft) = 24.5 sec
Average amount of liquid collected per nozzle for 24.5 sec = 525 mL
Nozzle spacing on the boom = 0.5 m (20 in.)

Application rate = \[
\frac{252 \text{ mL} \times 0.2}{0.5 \text{ m}} = 210 \text{ L/ha}
\]

- 210 L/ha × 0.4 = 84 L/acre
- 210 L/ha × 0.09 = 18.9 Imp. gal/acre
- 210 L/ha × 0.11 = 23 U.S. gal/acre

Band Spraying: The same formula can be used to calibrate when banding. Instead of using nozzle spacing in metres, use width of area sprayer per nozzle in metres.

Hand-Held/Backpack Sprayer Calibration

Many people use small hand-held or backpack sprayers for treating problem areas or spraying areas that were missed. Calibration of these sprayers is as important as calibrating your field sprayer.

Method I

1. Measure an area that is 100 m$^2$.
   e.g., 10 m × 10 m, or 25 m × 4 m

2. Fill the spray tank with water. Mark the level on a measuring stick. Pump to the pressure that will be used during the pesticide application.

3. Spray the water over the 100 m$^2$ area. Walk at a steady pace, taking care to apply it as evenly as possible, just as you would when applying pesticide.

4. Measure the amount of water needed to refill the spray tank to the mark on the measuring stick. This amount will be the sprayer output per 100 m$^2$.

NOTE 1: Sprayer-calibration bottles or kits are available from a number of suppliers. For further information contact your local office of the Ontario Ministry of Agriculture, Food and Rural Affairs or manufacturers of sprayers, sprayer parts or herbicides.

NOTE 2: For banded-spray applications, measure the width of the spray band (at the soil surface or surface of the crop canopy) and enter this value into the formula instead of the “nozzle spacing”. Note that in band spraying the acreage sprayed is not the same as the crop acreage. (When broadcast spraying a row crop with 1 m rows, the whole field is treated. A band spray may only treat 30 cm over each row. Therefore, only about 1/3 of the field is actually treated.) The herbicide rates referred to in most herbicide publications and labels refer to the actual area sprayed unless otherwise stated.
**Method II**

1. Set 2 stakes 50 m (164 ft) apart in the field.
2. Half-fill the sprayer with water.
3. Walk the 50 m three times at a steady pace. Calculate your average time to travel the 50 m.
4. Measure the width of the band sprayed by the nozzle (in metres) at your walking pace.
5. Pump the sprayer for the same amount of time as calculated in step #3, collecting the liquid from the nozzle in a measuring device.
6. Application rate (L/ha) = 
   \[
   \text{mL liquid per nozzle} \times \frac{0.2}{\text{Band width (metres)}}
   \]

**Method III**

1. Partially fill sprayer. Pump to the pressure you will use during the pesticide application.
2. Spray to determine width of swath (in metres).
3. Walk at a steady pace for 15 seconds. Measure the distance (in metres).
4. Multiply spray width times distance travelled to provide the area (in square metres) sprayed in 15 seconds.
5. Spray into a measuring device for 15 seconds – gives amount of solution sprayed in 15 seconds.
6. Application rate (L/ha) = 
   \[
   \frac{\text{amount sprayed}}{\text{area (length} \times \text{width)}} \times \frac{L \times 10,000}{\text{sq. metres}}
   \]

To convert the application rate of any pesticide to the amount required for a small area, follow this guide:
- 1 kg/ha = 10 grams/100 m²
- For liquid measure, 100 L/ha = 1 L/100 m²


**Determining Amount of Herbicides Needed**

**Determining Amount of Product per Hectare**

Most rates suggested in this publication are given in terms of both active ingredients (common name) per hectare and product (TRADE NAME) per hectare. However, where the amount of active ingredient in the formulations varies considerably (for example, glyphosate is available in concentrations of 360 g/L, 480 g/L, 500 g/L and 540 g/L) The rate may be given in terms of active ingredient only.

**Determining Amount of Product Required per Tankful**

After determining how much commercial product is needed per hectare, calibrate the sprayer and determine the number of hectares each tank will cover. Determine the quantity of herbicide needed to add to the spray tank using the following formula:

\[
\text{Area covered per tankful} = \frac{\text{sprayer tank size (Litres)}}{\text{Application Rate (L/ha)}} \times \text{hectares}
\]

\[
\text{Product required/tank} = \frac{\text{hectares covered by tank}}{\text{product rate/ha}}
\]

**Sample Calculations**

(a) \[\text{product/tank} = 4.1 \text{ ha} \times 2.2 \text{ kg/ha} = 9.02 \text{ kg LOROX/tank}\]

(b) \[\text{product/tank} = 4.1 \text{ ha} \times 2.1 \text{ L/ha} = 8.61 \text{ L AATREX/tank}\]

Follow manufacturer’s recommendations on mixing order and procedures.

**Materials, Mixing and Mixtures**

Dry herbicide formulations include granules, soluble powders and wettable powders. Granules do not require prior mixing into a slurry. They are ready to be mixed in water. Soluble powders can be dissolved in water. Wettable powders will not dissolve but will form a suspension that requires constant agitation.

Liquid herbicide formulations either mix in water to form a solution or may be oil-based and form an emulsion that will require agitation.
Pesticide labels usually provide mixing directions for registered tank-mixes, often describing the order of mixing. Whenever a label provides mixing directions, they should be followed. Consult the package labels for information on the compatibility of different herbicide products as certain formulations may react when mixed together, resulting in materials with different properties and activities than the original ones. If the pH or hardness of the water requires adjustment, adjustments should be made prior to the addition of spray material to the tank.

When the label does not provide mixing instructions for a registered tank-mix, pesticides should generally be mixed using the following procedure:

- Fill the spray tank with water to ⅓ of the total spray volume required and start agitation. Add the different formulation types in the order listed below, allowing time for complete mixing and dispersion after adding each product.
  1. dissolvable packs
  2. wettable powders
  3. water dispersible granules and dry flowables
- Maintain agitation and fill spray tank to ¾ of total spray volume. Then add:
  4. water-based solutions
  5. emulsifiable concentrates
  6. spray adjuvants
- Finish filling the spray tank to the required volume, Maintain continuous agitation during mixing and final filling, and throughout application.

Mixtures of different herbicides or mixtures of herbicides with pesticides or foliar fertilizers should not be applied in a single application unless registered for use in this way.

Unless specifically mentioned in this publication, or on a herbicide label, the addition of a surfactant or a detergent to a spray solution is not recommended.

Where water is known to have an excessive salt content, compatibility of the water and the chemical at field strength should be tested first on a small scale. See note on Agitation in the Care and Use of Equipment section, page 12.

Application Indicators

**Colourants/Foam Markers for Pesticides Application**

Colourants added to the pesticide solution help show where pesticides have been applied. Foam marking systems help minimize overlap. Adding a colourant to the basal sprays of herbicides on cut stumps of woody plants helps assure thorough coverage without respraying. Examples of colourants are listed below.

- Blazon: blue, water soluble
- Bas-oil Red : red, oil soluble
- Red Dye Foam

Colourants are available from agricultural chemical dealers.

Additional Information

**Video**

- How to Manage Spray Drift
- Spray Drift Reduction Through Air Induction
- Field Sprayer Calibration

**Available from:**

Ontario Pesticide Education Program
Phone 1-800-652-8573
www.opep.ca

OMAFRA Factsheets

- Six Elements of Effective Spraying in Orchards and Vineyards
- How Weather Conditions Affect Spray Applications (web only)
- Ways to Avoid Pesticide Spills
- Calibrating Airblast Sprayers
- Adjusting, Maintaining and Cleaning Airblast Sprayers
- Pesticide Contamination of Farm Water Sources
- Pesticide Drift from Ground Applications
- Farm Pesticide Storage Facility

Pesticide Drift

Do you know what pesticide drift looks like or what you can do about it? OMAFRA and CropLife Canada have created two short videos with innovative visual demonstrations using dyes and night-spraying to show what drift actually looks like. See how spray particles behave and discover what changes can be made to your spray program to greatly reduce the risk of pesticide drift. Learn more at ontario.ca/spraydrift.