4 Sprayer Information

4.1 Reducing Risk of Pesticide Exposure Through use of Engineering Controls

Why Use Engineering Controls?

Handling and applying pesticides is risky business. Keeping pesticide exposure to a minimum should be a chief concern of any pesticide applicator. This section describes various devices known as engineering controls that can help reduce applicator exposure to pesticides in five areas of potential contamination.

1. Loading the Sprayer

Closed Transfer Systems - Closed transfer systems allow concentrated pesticide to be moved from the original shipping container to the sprayer mix tank with minimal or no applicator contact. Many systems provide a method to measure the concentrated pesticide. Some systems also include a container rinsing system. Currently available closed transfer systems use a probe inserted into the pesticide container, a connector on the container that mates to a similar connector on the application equipment, or a vacuum-type system that uses flowing water to transfer the chemical from the container.

Induction Bowls - Induction bowls are metal, plastic or fiberglass hoppers attached to the side of the sprayer or nurse tank that allow pesticides to be added to the mix tank without the applicator climbing onto the spray rig. Pesticides are poured into the bowl and water is added to flush out the bowl and carry the pesticide to the spray tank. Often a rinse nozzle is mounted inside the bowl for rinsing out empty pesticide containers. Typically induction bowls are raised out of the way during spraying and lowered to about 3 feet above ground when loading the sprayer.

Direct Pesticide Injection System - Direct pesticide injection systems allow pesticides to be mixed directly with water in the sprayer plumbing system rather than in the main spray tank. The pesticide is pumped from its container and mixed with the water either in a manifold or at the main water pump. Only clean water is held in the main sprayer tank. An electronic controller and a series of pumps adjust the amount of concentrated pesticide that is injected into the water stream, allowing for variable application rates.

Container Rinse System - Container rinse systems consist of a rinse nozzle and a catch bowl that traps the container washings (rinsate). The empty container is placed over the rinse nozzle and a jet of water cleans the inside of the container. The rinsate caught in the bowl is pumped into the spray tank to be used along with the spray mixture. Often rinse nozzles are installed in chemical induction bowls. Most closed transfer systems also provide a way of rinsing containers and piping the rinse water into the spray tank.

2. Reducing Contamination at the Boom

Boom Folding/Extending - Manually folding booms can be a major source of operator contamination because the boom can be covered with pesticide from drift or dripping nozzles. Consider the use of hydraulic or mechanical folding methods.

Diaphragm Check Valves - Typically, when a sprayer is shut off and as the system pressure drops, any liquid remaining in the boom piping drips from the nozzles, possibly dripping onto the boom or even the operator. Diaphragm check valves installed at each nozzle prevent this by using a spring-loaded rubber diaphragm to close off the flow of liquid once the system pressure drops below about 10 pounds per square inch. When the sprayer is switched on and system pressure builds up, the valve opens and allows the liquid to flow through the nozzles.

Multiple Nozzle Bodies - Contamination can occur when operators change or unclog nozzles during an application. Multiple nozzle bodies (or turret nozzles) allow operators to switch between nozzles with a turn of the nozzle body rather than having to unscrew or undo a threaded or a bayonet fitting.

Hand Wash Water Supply - Providing adequate wash water is essential (and may be legally required). A simple container with a hand-operated valve can be mounted on the side of the sprayer to provide clean water for hand washing and personal hygiene.

3. Protecting from Drift and Contaminated Clothing in Cabs

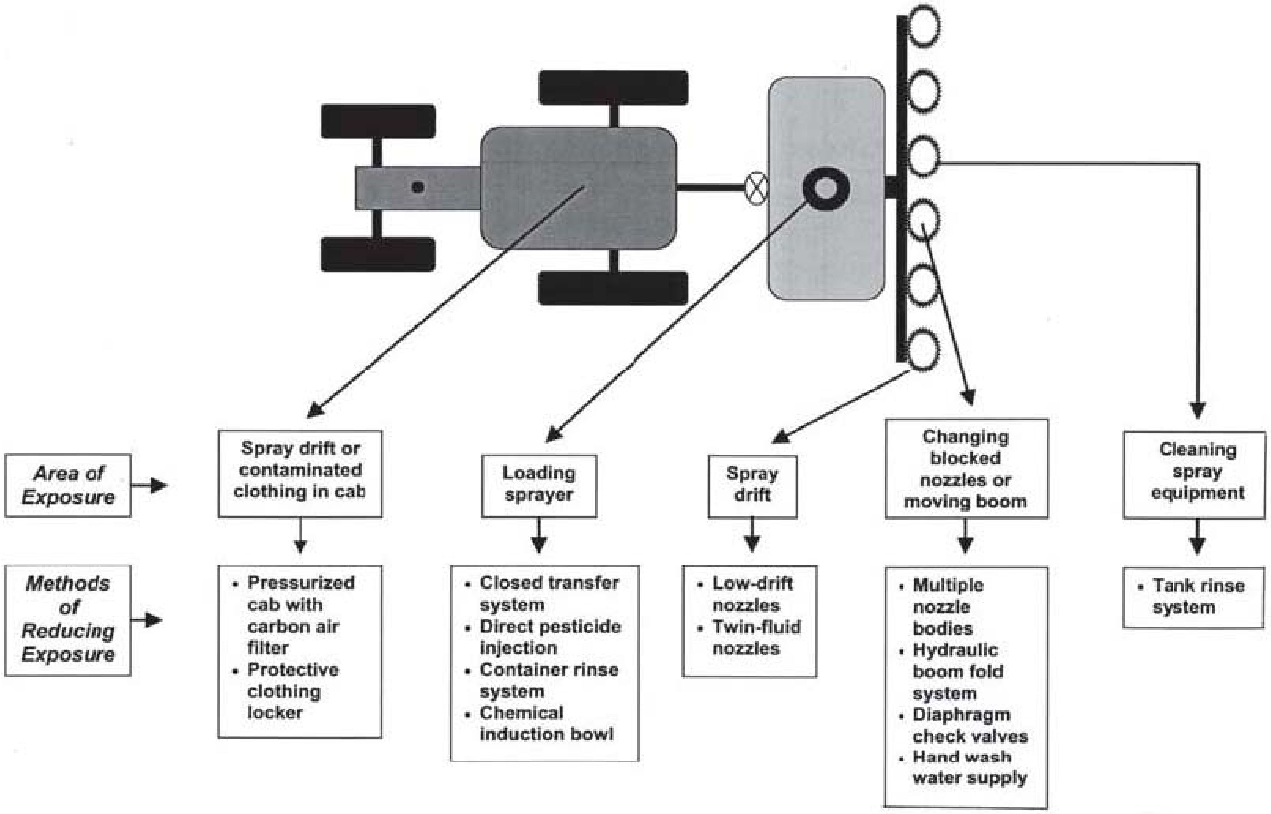
Cab Filtration Using Carbon Filters - Carbon filtration systems are used to remove pesticide odor and pesticide-laden mist from fresh air used in a tractor or self-propelled sprayer cab. Carbon filtration systems are often a standard feature on self-propelled sprayers. Many factory installed tractor cabs offer optional filtration systems. Cabs certified under the American Society of Agricultural Engineers (ASAE) standard meet the requirements for enclosed cabs contained in the EPA Worker Protection Standard.

Protective Clothing Lockers - To prevent contamination of the tractor or sprayer cab interior when entering the cab, some sprayers have a compartment mounted to the side or front where protective clothing can be stored. Alternatively, a locker can be fitted to the nurse tank.

4. Controlling Drift

Low-Drift Nozzles - Low-drift nozzles create larger droplets than conventional nozzles. The larger droplet sizes are less prone to drift, reducing environmental and operator contamination.

Areas of Potential Pesticide Exposure Risk and Engineering Controls to Reduce Exposure



Air Induction (Twin Fluid) Nozzles - These nozzles allow air to mix with the spray liquid, creating large, air-filled droplets that have virtually no fine, drift-prone droplets. The frothy droplets explode when they contact their target and offer similar coverage to droplets from conventional, finer-spray nozzles.

5. Cleaning the Sprayer

Tank Rinse Systems - Tank rinse systems consist of a clean water supply tank mounted to the sprayer and one or more rotating discs or nozzles mounted inside the main sprayer tank. Water is pumped from the clean water tank to the rinse nozzles, which spray water around the inside of the spray tank. These systems allow tank rinsing in the field thus removing the need to return to the filling station, and allow tank rinsate to be applied to the sprayed area.

4.2 Minimizing Pesticide Drift in Orchards

Spray drift of pesticides is an important and costly problem. Drift can affect neighboring properties, create concern about potential pesticide poisoning, damage susceptible off-target crops, and cause environmental contamination to waterways. Pesticide that drifts off-target is a wasted investment that does not contribute to pest suppression.

There are two types of drift. Airborne drift, often very noticeable, and vapor drift. Airborne drift is influenced by many interrelated factors including droplet size, nozzle type, sprayer design, and operator knowledge and attention to detail. The amount of vapor drift will depend upon atmospheric conditions such as humidity, temperature and the product being applied, and can occur days after an application is made

4.2.1 Factors Affecting Drift

4.2.1.1 Droplet size

Optimum droplet size is a compromise between smaller diameter for better coverage and larger diameter to minimize off-target drift. Droplets of 150–250 microns diameter provide a balance between good coverage and minimal drift.

Droplets of less than 50 microns have insufficient momentum for impact and can remain suspended in the air indefinitely or until they evaporate. A 100-micron droplet takes about 11 seconds to fall ten feet in still air; if released into a 5mph wind it will drift about 75 feet before hitting the ground. Droplets larger than 250 micron diameter may bounce off the target.

For a given nozzle, increasing the operating pressure decreases the average droplet size. If not set up properly, air blast sprayers can produce a high proportion of spray as drift-prone small droplets. Drift reduction spray surfactants can reduce the proportion of driftable small droplets.

4.2.1.2 Nozzle type and size

Air induction nozzles produce larger droplets than conventional cone nozzles. Large droplets normally roll off the leaf, but air inclusion nozzles create air bubbles within the larger droplets, which then collapse on contact with the leaf, dissipating the energy and dispersing the liquid. Air induction nozzles, when used properly, can reduce drift by at least 50 percent while maintaining good coverage. Note, that not all AI nozzles are alike, many are only suitable for use at lower pressures than desirable for airblast sprayers. TeeJet recently introduced high pressure AITX air induction nozzles designed for use at 150-300 PSI suitable for most airblast sprayers. These nozzles are recommended as a significant technical improvement for orchard spraying.

Rotary atomizers create smaller, but more uniform, droplets. When used in conjunction with a tower or cross-flow fan design, the smaller droplets are directed into the canopy. This type of sprayer, often called “controlled droplet application”, produces 95–98% of its droplets within a narrow size spectrum. The droplet size produced depends on the speed of the spinning cage. Advantages include being able to spray with less water, resulting in better timeliness and a more targeted spray. Controlled droplet application is more commonly used for herbicide boom sprayers in tree fruit orchards, but may also have potential for canopy sprays, though this potential has not been thoroughly investigated.

4.2.1.3 Sprayer design and accessories

Tower sprayers and tunnel sprayers are better than conventional axial fan airblast sprayers at targeting the spray into the canopy, thus reducing drift and increasing deposition. Tower sprayers, using an air curtain that gives horizontal penetration into the canopy, have shown excellent results at disease and insect control.

Tunnel sprayers have tremendous advantages in orchards with trellised or dwarf trees. A spray collection device at the base of the tunnel canopy recirculates spray drip with subsequent savings in pesticide and 90% drift reduction. Tunnel sprayers combined with air induction nozzles can give 99% drift reduction. When first introduced, some growers thought that tunnel sprayers were only suitable for level land, but an increasing number are to be found in orchards on undulating land.

Drift problems increase when a space occurs within the tree row. Orchard sprayers can be fitted with ultrasonic or infrared canopy sensors to detect the shape of a tree and adjust the spray pattern accordingly. This helps to reduce drift, ground deposition, spray volume, and pesticide use.

For herbicide application, shielded sprayers prevent drift from contaminating fruit or damaging leaves or trunks. They allow growers to apply herbicides in a wider range of weather conditions. Other herbicide drift reduction tools include flat fan nozzles, controlled droplet applicators, and spray adjuvants.

4.2.1.4 Sprayer calibration

Correct calibration ensures that all the nozzles are discharging the correct volume for the chosen tractor speed, and that nozzle orientation with respect to air movement generates the desired spray pattern. Operators must set the air deflectors correctly to confine airflow and spray pattern.

4.2.1.5 Weather and Wind

Wind speed and direction, relative humidity, temperature and atmospheric stability all affect drift. Windbreaks can be used to reduce off-target drift. Windbreak height and density affect drift, and may, in certain conditions, create additional air currents and eddies. There are so many variables such as topography and wind direction that it is difficult to make general conclusions about windbreak efficacy for drift reduction.

4.2.2 Drift Management Practices

4.2.2.1 Forward planning

Forward planning is the key to good management. Choose the correct size sprayer with good back-up support to ensure that spraying may be done in a timely manner. The use of orchard field cards, detailing the block name, pesticide required, amount of each pesticide per tank, mixing order etc. reduces stress, improves efficiency and safety. Integrated pest management (IPM) monitoring of pests and disease forecasts should be done to allow sufficient time to apply a needed pesticide where needed.

Many of the factors that affect drift are important for good coverage and effective pest management. Good spray practices that prevent pesticide going where it is not wanted, also improve targeting for where it is needed.

4.2.2.2 Before Spraying

1. First, here are a few options that may not be immediately practical, but are worth considering for the long term. Planting windbreaks or installing overhead hail nets can substantially reduce drift (up to 75 percent for hail nets.) Acquiring a tower or tunnel sprayer is an effective response for blocks with heightened drift concerns.
2. An immediate and inexpensive upgrade for a conventional airblast sprayer is to switch to air induction nozzles.
3. Calibrate the sprayer to ensure that everything is working correctly (see next section for details).

Choose a lower range spray pressure ensure that the pressure gauge is accurate. Select the proper nozzles, and replace nozzles that show deviation during sprayer calibration. Adjust nozzles to achieve correct distribution within the canopy, particularly as the growing season progresses. Adjust fan speed to fit tree height and canopy density.

One method to check spray coverage is to use a patternator. Another method is to use a 16-foot high pole (two 8' 2" x 4" boards end to end) with a paper tape stapled along the leading edge. Place the pole between two trees within the row and spray a mixture of clean water and food coloring. Travel between the rows, spraying out the mixture. The spray will stain the paper where it hits. By looking at the colored spray droplets on the paper, you can adjust the orientation of nozzles or deflectors until the spray is only hitting the portion of the vertical pole that is desirable.

Spraying some test trees with Surround will indicate canopy coverage and also how much spray is blowing right through the trees onto the grass in the next row. Set PTO or fan speed for the minimum needed to get coverage throughout canopies but not so high as to blow through the canopies.

'Cornell Doughnuts' are homemade attachments that restrict air intake to the fan cage to reduce air flow. For early season, a 1/2 air intake doughnut can be used to only allow enough air to penetrate just the target row. A 2/3rd air intake hole can be used for early/mid-season to allow more air.

A single doughnut made from two layers of plywood with matching sets of cut-through holes allows for adjusting the air flow by rotating the two sheets to increase or decrease the overlap of the cut-through holes to change the air restriction.

German Drift Reduction Classifications and Methods – Adapted from: BBA-Register "Drift reducing spraying equipment". BBA-Verzeichnis Verlustmindernde Geräte, Bundesanzeiger, 10.2.2001

Nozzle Key: ID = Lechler Air Induction; TD = Agrotop by GreenLeaf; AVI = Albuz Air Induction; DG = Drift Guard by TeeJet; AD = Lechler Drift Reducing.

Drift Reduction Class	Sprayer	with Nozzle Types	with Practice
50%	All air assisted sprayers	With ID, TD, AVI, DG, AD nozzles	Spray first 5 rows without air towards edge.
	All air assisted sprayers	All types	Hail nets above trees.
	Air assisted sprayers with axial fan.	ID Various Sizes, TD 80-02 Keramik, AVI 80-03	Spray pressure max 58-73 PSI – Plus – Spray first 5 rows with reduced fan output (max 30,000 m3/h)
	Foliage Detector sensor	All types	
75%	All air assisted sprayers	ID, TD, AVI, DG, AD	Hail nets above trees.
	Tower Sprayer or Sprayer with cross flow fan	ID, TD, AVI, DG, AD	Spray first 3 rows without air towards edge.
	Air assisted sprayers with axial fan.	ID Various Sizes, TD 80-02 Keramik, AVI 80-03	Spray pressure max 58-73 PSI + Plus + Spray first 5 rows with reduced fan output (max 20,000 m3/h).
90%	Tower sprayers with fan or Sprayer with cross flow fan. Lipco Tunnel sprayers	ID, TD, AVI, DG, AD	Spray first 5 rows without air towards edge and with reduced spray pressure, or with air induction nozzles.
99%	Lipco Tunnel sprayers	With air induction nozzles.	

4. Train the operator to use the sprayer correctly on your farm under your conditions. Purchase and use good quality instruments for wind speed, temperature and humidity.
5. Plan ahead to minimize the time needed for measuring pesticide and refilling spray tank water. As much as possible, start early to allow extra time so that if wind speed or other conditions are not favorable you will not feel pressed to spray anyway, but have flexibility to wait for better conditions.
6. Read and follow each pesticide label. Consider spray additives to reduce drift.
7. Consider using orchard field cards to make as many decision ahead of time, simplify mixing, reduce the chance for errors, and to minimize delays.
8. Only spray when weather conditions are ideal; avoid spraying on days when conditions are favorable for atmospheric inversion or wind drift.

4.2.2.3 During Spraying

1. Drift-reducing additives. A number of manufacturers supply drift reducing agents; most work via increasing droplet size. Beware, not all of these products can withstand the higher pressures associated with airblast sprayers and have not been verified with field tests.
2. Stay alert! Ensure the spray is not allowed to drift on to non-target areas and watch for changes in wind speed and direction.
3. Maintain a constant speed and pressure. If an automatic regulator is fitted; remember that a small increase in speed can result in a large increase in pressure. The delivered air and spray must be given time to penetrate the canopy.
4. Use a 50–100-ft buffer zone around sensitive crops or waterways. Spray with one side of the sprayer into the orchard for at least 50 feet from the orchard boundary to create a “headland”. A shroud can be used to block any air on the opposite side of the sprayer. This can reduce drift by 50 percent.

4.2.2.4 Conclusion

Drift is impossible to eliminate but can be minimized. Implementing these methods will greatly reduce the extent of drift, improve efficiency of spray application, save time and money while providing better results.

4.3. Preparing an Air Blast Sprayer

4.3.1 Checking the Sprayer

Sprayers must be regularly checked over to ensure that proper maintenance has been carried out and that no outstanding repairs need to be done. Faulty sprayers contribute to increased drift levels and waste money through inefficiency and overuse of chemicals.

Maintenance measures such as fitting a new set of nozzles at the beginning of each season also save money. Even when there is overdosing by as little as 5%, the cost of a new set of nozzles would be recovered in less than a day’s work.

Caution

- ☐ Take great care when adjusting a sprayer while the tractor engine is running.
- ☐ Always ensure that the fan is stationary before approaching the rear of the sprayer.
- ☐ Engage the handbrake when leaving tractor seat.

4.3.2 Fitting the Sprayer to the Tractor

The selected tractor must always be powerful enough to operate the sprayer efficiently under the working conditions that will be encountered. All its external services–hydraulic, electrical and pneumatic–must be clean and in working order. Tractors fitted with cabs must have efficient air filtration systems. All protective guards must be in place. Trailed sprayers are often close-coupled to the tractor, so it is essential that the drawbar and the PTO shaft are correctly adjusted for turning. PTO shafts must be disengaged when making very tight turns.

4.3.3 Checking the Operation of the Sprayer

Partly fill the tank with clean water and move the sprayer to uncropped ground. Remove the nozzles. Although not using any chemical at this point, get into the habit of wearing a coverall, gloves and a face visor when working with the sprayer. Engage the PTO and increase speed slowly to operating revs. Test the on/off and pressure relief valves, and check the agitation system. Flush through the spray lines, then switch off the tractor. Refit the nozzles and check the liquid system again for leaks.

It is a valuable exercise to assess the spray deposits at various points in the canopy and on upper and lower leaf surfaces of the trees to be sprayed. This is particularly important if the foliage is dense or if the trees are grown in beds of three or more rows. Water-sensitive papers, food coloring or fluorescent tracers are available for this purpose. An increase in spray volume or adjustment of the nozzles and their locations may be necessary in order to achieve the correct deposits.

4.3.4 Pre-Season Maintenance Checklists

Hoses

Check…

- ☐ for splits and cracks
- ☐ connections to ensure they are water-tight
- ☐ for hose chafe, particularly in routing clips

Filters
Check…

- ☐ for missing filter elements and seals
- ☐ for leakage
- ☐ for blocked or damaged filters

Tank
Check…

- ☐ for fractures and any other damage
- ☐ the tank sits firmly in its mount
- ☐ the securing straps are correctly adjusted
- ☐ the agitation is working
- ☐ the tank is clean

Controls
Check…

- ☐ the control circuitry (electrical, hydraulic or air) for correct operation
- ☐ valves for both internal and external leaks

Pump
Check…

- ☐ lubrication levels
- ☐ for leaks
- ☐ the air pressure in the pulsation chamber (if fitted) is at the recommended level
- ☐ that pump rotates freely without friction or noise. Do so by rotating manually or starting at low speed (corrosion may cause seizing up)

Pressure Gauge
An accurate pressure gauge is vital for accurate sprayer setup. The cost of replacing a faulty pressure gauge which has been indicating at 15% below the actual pressure is recouped in about two hours of operation.

Nozzles
Check…

- ☐ all nozzles are in good condition, with no leaks around the body
- ☐ all nozzles are clean and free from obstruction (note: clean with a soft brush or airline – don't damage nozzles by using wires or pins)
- ☐ all nozzles deliver to within + or - 5% of the manufacturer's chart value

Using water only, set to 'spray' at the specified pressure and collect the output from each nozzle in turn for a period of 60 seconds. Record each output and replace those outside the 5% tolerance stated in the manufacturer's chart.

Automatic controllers
If the sprayer has automatic controllers to monitor the speed of the sprayer and the flow, pressure and area sprayed:
Check…

- ☐ they are in good condition and properly maintained
- ☐ they are frequently calibrated for accuracy, leaks, blockages, variations in pressure or any minor damage during spraying

Routine Maintenance
The following checks should be carried out routinely:

- ☐ All hoses are tightly connected and free from sharp bends; cracked or damaged hoses must be replaced.
- ☐ All controls move freely and are fully adjustable.
- ☐ Pressure gauge reads zero.
- ☐ Pump can be turned over by hand.
- ☐ Fan turns freely and is not obstructed; bearings are sound and lubricated.
- ☐ Air pressure in pump accumulator (if fitted) is correctly adjusted.
- ☐ Drain plugs and clean filters are in position.
- ☐ Tires on trailed machines are sound and correctly inflated; wheel nuts are tight.

4.4 Sprayer Calibration

Accurate calibration of orchard spray equipment is equally important for efficient effective use of pesticides as choosing the right chemical and timing of its application. Tree spraying requires a sprayer with adequate capacity to distribute the spray evenly throughout the trees. Individual sprayers can be designed to operate most effectively over a range of gallonages per acre. The best spray coverage and deposit are obtained within the manufacturer specifications for a particular sprayer. Sprayer performance will be limited by pump output, pressure setting, fan capacity, and travel speed. In order to determine the desired sprayer output for a chosen spray concentration (e.g. 2X, 4X or 6X), you first need to know how much water would be needed for a dilute 1X application. The Tree Row Volume formula is a method to estimate the dilute gallons per acre according to tree height, canopy width, row spacing, and canopy density.

4.4.1 Tree Row Volume

4.4.1.1 Dilute Applications

Before the widespread adoption of semi dwarf and dwarf rootstocks, orchards of free-standing apple trees on standard rootstock were relatively uniform in their spray volume requirements, and pesticide dosages were defined on a per acre basis assuming that all orchards required 400 gallons per acre for a dilute spray application. A dilute spray application is the amount of water needed to saturate the foliage such that any additional spray would just run off the leaves. This is sometimes called “spraying to drip”.

Today’s orchards are less uniform that in previous decades, and often contain a variety of different size-controlling rootstocks and planting systems. Assuming a uniform 400 gallons per acre for dilute spray requirement is not accurate for today’s orchards of various tree sizes. The Byers Tree Row Volume (TRV) formula is a simple method to estimate the dilute spray volume required for different tree sizes and spacings. We use the Byers TRV formula here because it is the one most commonly used, has been subjected to validation testing, and is simple and easy to use. There are alternate TRV formulas. The differences in the estimate of dilute gallons per acre given by different TRV formulas are relatively minor.

The estimate for the dilute gallons per acre is used to determine how much water is needed to apply a pesticide at 2X, 4X, or 6X etc. concentration.

It would be nice if the explanation above covered all situations, but it doesn’t. After reading the description of how to use TRV below, be sure to reading the subsequent comments about the limitations, complications, and controversy around TRV.

Tree Row Volume =
Tree height X Canopy width X Row length per acre

Tree row volume (cubic feet per acre) =	Tree height (feet)	x	Canopy density (feet)	x	43,560 sq ft per acre / distance between rows (feet)

Example:
Trees 11 feet tall and 12 feet wide in rows 20 feet apart

Tree row volume (cubic feet per acre) =	11	x	12	x	43,560 / 20

Tree row volume (cubic feet per acre) =	120 x 2178	=	287,496 cu. ft.

Converting canopy volume per acre into dilute gallons of spray per acre

The Byers Tree Row Volume assumes 0.7 to 1.0 gallon dilute spray is needed for each 1,000 cubic feet of tree canopy volume. For well-pruned orchards, the 0.7 gallon/1,000 cubic feet conversion has been used successfully by many growers over many years. The maximum of 1.0 gallon/1,000 cu ft should be used in an unpruned orchard with a thick canopy.

Changes in canopy density through the season, or for different blocks, may require other adjustments to spray pattern and fan output. Without such adjustments, poor coverage can lead to inadequate pest control or excessive application, or a combination of both from uneven coverage. By setting up the sprayer for the largest trees to be sprayed, adjustments can be made for smaller trees by turning off nozzles and reducing fan output.

Some spray trials have found better results by increasing the calculated value for dilute gallons per acre to adjust for changing canopy thickness as vegetative growth thickens canopies through the growing season. But it is too complicated to recalibrate sprayers between applications. Instead, the adjustment for increasing canopy density can be made by using a constant spray volume per acre and using a sliding dilute gallons per acre value to define what spray concentration the constant gallons per acre represents. If doing growth stage adjustments, the dilute gallons per 1,000 cubic feet can increase from 0.5 gallon at Green Tip, to 0.7 gallon at Petal Fall, to 1.0 from terminal budset in July through harvest.

But it bears repeating that the main point is to calibrate the sprayer on the basis of 0.7 gallons per 1,000 cubic feet. Going beyond that is potentially useful fine tuning.

In the example above for an orchard with trees 11 feet tall, 12 feet wide, and with 20 foot row spacing, the tree row volume was 287,496 cubic feet per acre. Using 0.7 gallons dilute spray for each 1,000 cubic feet gives an estimate of 201 gallons per acre for a dilute spray.

Dilute gallons per acre =	287,496 cu. ft.	x	0.7 gal. per 1,000 cu. ft.	=	201 gals.

However, if the trees are not well pruned, or for late season applications when getting thorough coverage requires more water, a higher value of 1.0 gallon for each 1,000 cubic feet of canopy can be used to estimate the amount of dilute spray needed.

Dilute gallons per acre =	287,496 cu. ft.	x	1.0 gal. per 1,000 cu. ft.	=	287 gals.

It is best to use the average tree height, canopy width (looking down the row from branch tip to branch tip), and row spacing values measured in your orchard. Table 4.4.1 shows some examples of TRV-based dilute gallons per acre values for some different scenarios.

Table 4.4.1. Gallons of dilute spray per acre required to provide equivalent coverage for apple trees of different sizes and spacings.

Distance Between Rows (feet)	Tree Width (feet)	Tree Height (feet)	Dilute spray Per acre[1] (gal/acre)
40	28	20	427
40	28	16	342
30	20	15	305
25	16	14	273
22	14	13	252
20	12	12	220
18	10	12	203
16	8	10	152*
14	6	10	131*
12	5	10	127*
11	4	10	111*
10	3	9	82*,@

[1]Minimum dilute gallons per acre = tree height x canopy width x linear feet of row per acre (43,560 divided by distance between rows) x 0.7 gallon per 1,000 cu ft of tree volume.
* For pesticide applications, basing dosage on a mimimum of 200 gallons dilute spray per acre is recommended.
@ For growth regulators, a 100 gallons dilute spray per acre thrshold is recommended.

4.4.1.2 Limits and Controversy for TRV

For very small trees factors such as spray capture efficiency (amount of water that blows through the canopy instead of landing on a leaf) can affect pesticide deposit. Because of this, investigators have defined a minimum dilute gallons per acre even if the calculated value is smaller. Spray trials suggest assuming a lower threshold of 200 gallons dilute spray per acre for setting pesticide dosage even if the calculated TRV dilute rate is smaller.

For thinners and other growth regulators, there is risk from over-application on very small trees, assuming a minimum of 200 dilute gallons per acre may be too high for very small trees. Expert opinion suggests a minimum dosage adjustment down to 100 gallons per acre may be more appropriate for thinners and growth regulators.

Many pesticide labels only state the dosage as a recommended amount per acre without giving explicit guidance on how to adjust that value for acres with different sized trees. Unfortunately, no uniform standard exists for defining what size tree is being assumed when a pesticide label states a dosage as a recommended amount per acre. Some labels give rate per acre with a statement that the per acre rate can be adjusted for smaller trees that require less than 400 gallons (most common) or 300 gallons per acre for a dilute spray. But other labels state a fixed rate per acre regardless of tree size without any other information.

Unless you can find a statement in the dosage recommendation about adjusting for smaller sized trees, the safest assumption from a pest control point of view is to assume that you must use the full rate regardless of tree size to be in full compliance with the label guidelines. Using a lower rate without any label statement about doing so can be seen as using an insufficient amount of product, and thus voiding any implied guarantee of pest control efficacy, or manufacturer compensation if a product fails to prevent economically significant pest damage.

TRV is controversial and complicated by other factors. Some growers, researchers, and manufacturers see using anything less than a fixed rate per acre as an invitation for unreliable results, poor control or increased risk of resistance. Other people look at the same facts and see TRV as an important tool to minimize costs and prevent overuse of pesticides in blocks of small trees. Another complication is that TRV adjustments that work for one product may not be suitable for another. Growers have to develop their own experience and opinions for deciding when and how to adjust spray material dosage for different size trees.

4.4.2 Concentrate Spraying

(Low Volume Application)

The best way to estimate a concentrate rate per acre is to use the Tree Row Volume formula described above and then dividing the dilute gallons per acre by the desired concentration factor.

$$\text{Concentration factor X} = \frac{\text{dilute volume of water per acre}}{\text{concentrate volume of water per acre}}$$

$$\text{Concentrate gals. per acre} = \frac{\text{dilute volume of water per acre}}{\text{Concentration factor}}$$

For the example orchard described above with an estimated 201 gallons per acre for a dilute spray, the concentrate gallons per acre would be as follows:

Concentration	Gallons per acre
1X = Dilute	201
2X	100
3X	67
4X	50
6X	33.5
8X	25

The limit for acceptable concentration factor depends on several factors, including the pest being controlled, density of foliage, weather conditions and the material being applied.

Table 4.4.1 shows other examples of how the amount of dilute spray required to cover an acre of orchard varies with tree size. An orchard with rows 30 ft apart and trees 20 ft wide x 15 ft tall, the dilute spray per acre is shown to be 300 gallons. Thus, if you are applying a pesticide recommended at a rate of 2 lb/100 gals. dilute, the appropriate per acre rate would be 6 lb. If those 6 lbs. of pesticide were applied using 75 gallons of water, then that would be 4X concentrate spray. Or if those 6 lbs. of pesticide were applied using 50 gallons of water then that would be 6X concentrate spray.

However, in an orchard with 22 ft between rows and trees 14 ft wide x 10 ft tall, the minimum dilute spray per acre is shown to be 200 gal. Thus, the same pesticide would be applied at a rate of only 4 lb per acre in this orchard (2 lb/100 gals. dilute x 200 gallons dilute per acre).

If the spray is applied at 67 gallons per acre, then the concentration is:

$$\frac{200 \text{ gal water/acre}}{67 \text{ gal water/acre}} = 3$$ Therefore, a 3X application

If the sprayer is applied at 50 gallons per acre, then the concentration is:

$$\frac{200 \text{ gal water/acre}}{50 \text{ gal water/acre}} = 4$$ Therefore, a 4X application

As the concentrate gallons of spray water per acre is reduced, errors become more critical. Concentrate sprays reduce or eliminate run-off, depending upon the degree of concentration.

High volume sprays of 1X (dilute) to 3X concentration are generally more effective for applying growth regulators, nutrient sprays, acaricides, and insecticides for control of pests such as scales and woolly aphid. For other foliar pesticide applications, concentration can be increased to 6X or 8X while retaining sufficient coverage for satisfactory results. Additional savings in cost of application above 8X concentration are minimal, and frequency of poor spray performance increases.

Remember there are different opinions about adjusting pesticide dose for concentrate spraying, and about using tree row volume estimate of dilute gallons per acre versus a fixed pesticide dose per acre.

1. For most pesticides, it is the amount of water that changes, not the amount of pesticide per acre
2. But for some materials, such as horticultural oil and some growth regulators, the amount of pesticide reduces in proportion to the water to maintain a constant concentration in the spray water regardless of how much spray is applied per acre.

4.4.3 Travel Speed Calibration

Travel speed is a critical factor in maintaining accurate application rates and will influence spray deposition depending on location within the canopy. The slower a sprayer travels, the greater the uniformity in spray deposition. Research studies have found that the higher the travel speed, the greater the variability in spray deposit. Variation in spray deposit is an important factor where uniformity of spray coverage throughout the canopy is required. The optimum speed varies by tree size, ground conditions, sprayer type, and time constraints. In general, 2 to 3 mph is the optimum range for most conventional axial fan airblast sprayers in most orchards.

Factors that will affect travel speed include:

- weight of sprayer to be pulled
- slope of terrain
- ground conditions (wheel slippage!)

The best way to measure travel speed is to pull a sprayer with tank half filled with water on the same type of terrain that the sprayer will be operated on.

Set up a test course at least 88 feet long, measure the course with a tape measure. Do not pace the distance. The longer the course, the smaller the margin of error. Run the course in both directions. Use an accurate stop watch to check the time required to travel the course in each direction. Average the two runs and use the following formula to calculate the speed in MPH.

Formula: $$\text{MPH} = \frac{\text{ft traveled}}{\text{seconds}} \times \frac{60}{88}$$

Example:

$$\text{MPH} = \frac{\text{88 foot course}}{\text{Traveled in 20 seconds}} \times \frac{60}{88}$$

MPH = 4.4 x 0.68 = 3.0 mph

Your figures:

Tractor gear _________ Engine revs.___________

____ feet traveled / ___ seconds x $\frac{60}{88}$ = ___ mph

4.5 Sprayer Output

The gallons of spray desired per acre and the time required to spray an acre determine the total rate of sprayer output for which the sprayer must be nozzled. Since volume of spray needed per acre varies with tree size, the most common row-spacing for the tree size to be sprayed should be used in calibrating the sprayer. Gallons of concentrate spray per acre is determined by dividing dilute gallonage by the concentration desired.

The total rate of output by the sprayer is calculated by dividing the gallons of concentrate spray by the time required to spray 1 acre.

$$\text{Minutes per acre} = \frac{\text{43,560 / Distance between rows}}{\text{MPH travel speed} \times 88}$$

Example for orchard with 20 foot row spacing and sprayer traveling at 2.5 miles per hour:

$$\frac{43{,}560 / 20}{2.5 \times 88} = \frac{2178}{220} = 9.9 \text{ minutes per acre}$$

Table 4.5.1. Approximate time required to spray 1 acre of orchard (two-sided sprayer operation, spraying both sides of trees).

Distance between Rows (feet)	Linear feet of Row/ acre[1]	Travel speed (mph)				
		1	1.5	2	2.5	3
		minutes per acre[2]				
40	1089	12.4	8.2	6.2	5.0	4.1
30	1452	16.5	11.0	8.2	6.6	5.5
25	1742	19.8	12.4	9.9	7.9	6.6
22	1980	22.5	15.0	11.2	9.0	7.5
20	2178	24.8	16.5	12.4	**9.9**	8.3
18	2420	27.5	18.3	13.8	11.0	9.2
16	2723	30.9	20.6	15.5	12.4	10.3
14	3112	35.4	23.6	17.7	14.1	11.8

[1]Linear feet of row per acre = 43,560 divided by distance between rows.

[2]Minutes per acre = linear feet of row per acre divided by speed in feet per minute. Speed in feet per minute = mph x 88.

4.5.1 Example for Setting Sprayer Output:

Example: Rows 20 feet apart, trees 12 feet wide x 11 feet high. A 3X concentrate application is to be made at a speed of 2.5 miles per hour.

1. The TRV formula indicates 200 gallons of dilute spray required per acre.
2. 200 (gal) divided by 3X = 67 gallons of 3X concentrate per acre required.
3. The minutes per acre formula and Table 4.5.1 indicate 9.9 minutes are required to spray 1 acre of 20-foot rows at a speed of 2.5 mph.
4. Total sprayer output for two-sided operation = 67 (gals. /acre) divided by 9.9 (minutes/acre) = 6.77 gallons per minute.
5. Output required per side = 6.77 divided by 2 = 3.38 gallons per minute per side.

4.6 Selecting Nozzles for Airblast sprayer

Following the previous example, to select air induction nozzle to apply output is based upon gallons/acre required above, let's say the sprayer pressure is 180 PSI.

$$\text{Gallons/minute} = \frac{\text{GPA x mph x row width in feet}}{495}$$

GPM = total sprayer output in gallons per minute,

mph = travel speed in miles per hour,

row spacing = number of feet between rows,

495 = a mathematical constant to correct units of measurement.

Example: We need to apply at 60 gallons/acre. We have an airblast sprayer with 6 nozzles each side and a comfortable forward speed for our ground conditions is 3mph. Rows are 18 feet apart.

$$\text{Gallons/minute} = \frac{\text{GPA x mph x row spacing}}{495}$$

$$\text{GPM} = \frac{67 \times 2.5 \times 20}{495} = 6.77$$

GPM = 6.77 gallons

Each side of the airblast manifold applies half that amount = 3.38 gallons per minute.

Let's say you want each of the top two nozzles on each side to each deliver 25% of the total spray volume per side, and each of the other 4 nozzles per side to each deliver 12.5% of the spray volume per side.

GPM for top nozzles is 0.25 x 3.38 = 0.85 gal. per minute
GPM for lower nozzles is 0.125 * 3.38 = 0.42 gal. per min.

As an example, using the TeeJet Spraying Systems catalogue # 50A, page 44 for AITX Air Induction Hollow Cone Spray Tip nozzles.

For the top two nozzles, read down the column for 180 psi until you find a value close to 0.85 gallons per minute. The 8004VK nozzle at 0.841 GPM is a very close

For the lower four two nozzles, read down the column for 180 psi until you find a value close to 0.42 gallons per minute. The 8002VK nozzle at 0.43 GPM is a good match.

.

		GPM														
		60 PSI	70 PSI	80 PSI	90 PSI	100 PSI	120 PSI	140 PSI	160 PSI	180 PSI	200 PSI	220 PSI	240 PSI	260 PSI	280 PSI	300 PSI
AITX†8001VK	50	0.121	0.130	0.138	0.146	0.154	0.168	0.181	0.192	0.203	0.214	0.224	0.233	0.242	0.251	0.260
AITX†80015VK	50	0.181	0.195	0.209	0.221	0.233	0.255	0.275	0.294	0.312	0.328	0.344	0.359	0.374	0.388	0.401
AITX†8002VK	50	0.247	0.267	0.286	0.303	0.320	0.351	0.379	0.405	0.430	0.453	0.476	0.497	0.517	0.537	0.556
AITX†80025VK	50	0.300	0.324	0.347	0.368	0.387	0.424	0.458	0.490	0.519	0.548	0.574	0.600	0.624	0.648	0.670
ATIX†8003VK	50	0.360	0.389	0.417	0.443	0.467	0.513	0.554	0.594	0.630	0.665	0.698	0.730	0.760	0.790	0.818
AITX†8004VK	50	0.480	0.519	0.556	0.590	0.623	0.684	0.740	0.792	0.841	0.887	0.931	0.974	1.01	1.05	1.09

Use the same procedure for alternate nozzle selection chart if using non-air induction one piece or disc-core hollow cone spray tips

4.7 Calibrating Airblast Sprayers

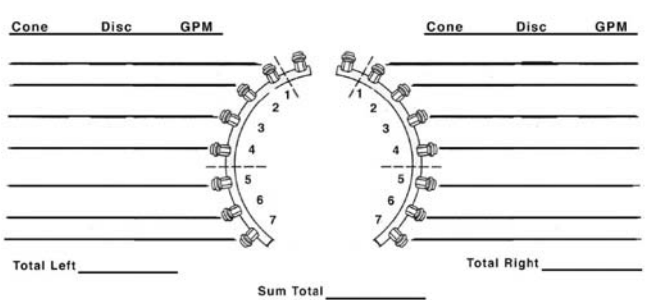
A simple vertical patternator can be constructed in the farm workshop using readily available materials; a build list and photographs can be found at: <http://www.nysaes.cornell.edu/ent/faculty/landers/pdf/Patternator.pdf>

Videos showing calibration and nozzle selection may be found on the internet at: <www.youtube.com>. Type in: "Calibration of airblast sprayers for orchards part 1 selecting and changing nozzles" or "Calibration of airblast sprayers for orchards part 2 measuring liquid flow"

4.7.1 Air Blast Sprayer Calibration (Use Clean Water)

1) Pressure check
   Place the pressure gauge on the nozzle fitting farthest away from the pump and turn the sprayer on. If pressure is lower at the nozzle than specified, increase pressure at the regulator.
   Pressure at nozzle _______psi
   Pressure at sprayer gauge _______psi
2) Nozzle output
   a. Use a flow meter (obtainable from Gemplers, Spraying Systems, etc.) attached to individual nozzles OR
   b. Connect hoses to each of the nozzles and measure the flow from each nozzle into a calibrated jug for one minute.

Remember 128 fl. oz. in one gallon. Example: If the output of one nozzle has been measured at 34.5 fl. oz. in one minute, then output per minute is divided by 128 = 0.27 GPM. Replace all nozzle tips that deviate more than 10% from their target rate.



GPM = gallons per minute = gal/min
GPA = gallons per acre = gal/acre
Formula:

$$\frac{\text{Total GPM} \times 495}{\text{mph} \times \text{row spacing (ft)}} = \text{GPA}$$

Your figures:

$$\frac{\text{\_\_\_\_\_ GPM} \times 495}{\text{\_\_\_\_\_ mph} \times \text{\_\_\_\_\_ ft}} = \text{GPA}$$

4.7.2 Calibrating a Kinkelder Sprayer (Use Clean Water)

$$\frac{\text{Rate of spray gals/acre} \times \text{Forward speed mph} \times \text{Row spacing ft} \times 60}{500} = \text{gals/hr delivery or index setting}$$

Your figures:

$$\frac{\text{gallons/acre} \times \text{mph} \times \text{ft} \times 60}{500} = \text{gals/hr delivery or index setting}$$

This figure should be set on both scales.

Both taps should be set on the distribution conduit in such a way that the index is set on the sign 162 on the index plate of the distribution conduit. The emission indication on the index plate has been fixed at a working pressure of 21 lbs (1.5 bar).

Check the output of the sprayer:

1. Divide the gallons/hour figure obtained above by 60 to give output/minute e.g., 162 gpm divided by 60 = 2.7 gallons/minute total of left and right side then divide 2.7 gallons/minute by 2 = 1.35 gallons/minute/side
2. Remove the plastic pipes from the nozzles on the left or right side, tie together and place in a measuring jug
3. Run the sprayer for one minute at correct engine speed, collecting the output in a measuring jug

Remember 128 fl. ozs in one gallon. Example: If the output of one side has been measured at 173fl. ozs, then output is divided by 128 = 1.35 gallons per minute.

4. Then check the output of the opposite side.

4.7.3 Calibrating an Agtec Sprayer (Use Clean Water)

1. Calculate the gallons/minute/side:

$$\frac{\text{Speed} \times \text{gallons/acre} \times \text{row width}}{1000} = \text{gallons/minute/side}$$

Your figures:

$$\frac{\text{mph} \times \text{gallons/acre} \times \text{ft}}{1000} = \text{gals/min/side}$$

2. Check AgTec tables for correct meter setting, select the gal/min as calculated above, and then find meter setting, e.g., meter #12 @30 psi gives 1.34 gallons/min.
3. Remove the hoses from the nozzles on the left or right side, tie together and place in a measuring jug
4. Run the sprayer for one minute at correct engine speed, collecting the output in a measuring jug

Remember 128 fl. ozs in one gallon. Example: If the output of one side has been measured at 173fl. ozs, then output is divided by 128 = 1.35 gallons per minute.

5. Then check the output of the opposite side.

4.8 Selecting Nozzles for Boom Sprayers

Step 1. Calculate the required nozzle output.

Formula:

$$GPM = \frac{GPA \times mph \times \text{nozzle spacing}}{5940\ (\text{constant})}$$

Example:

$$GPM = \frac{20 \times 4 \times 20}{5940} = GPM$$

$$GPM = \frac{1600}{5940} = .27\ GPM$$

If forward speed is too high (e.g. 4 mph) there will be boom bounce and boom yaw.

If pressure is too high, there may be drift, if too low there may be droplet bounce.

Example 1: Using a Spraying Systems catalogue #50A, page 12

Look at the columns headed GPA at 20" nozzle spacing.

Select the 4 mph column; look down the column until you see a figure close to 20 gpa, then look to the left to find the operating pressure.

For example:

a) select nozzle XR8003 or XR11003 at 30psi to give 19.3 gpa

b) select nozzle XR8004 or XR11004 at 20psi to give 21 gpa

Example 2 Look at column headed: Capacity of 1 nozzle in GPM

Read down column

a) select nozzle XR8003 or XR11003 at 30psi to give 0.26GPM or

b) select nozzle XR8004 or XR11004 at 20psi to give 0.28GPM

Nozzle	PSI	Drop size 80°	Drop size 110°	Capacity one nozzle in GPM	Capacity one nozzle in oz./min.	GPA (20") 4 MPH	5 MPH	6 MPH	8 MPH	10 MPH	12 MPH	15 MPH	20 MPH
XR8001 XR11001 (100)	15	M	F	0.061	7.8	4.5	3.6	3.0	2.3	1.8	1.5	1.2	0.91
	20	F	F	0.071	9.1	5.3	4.2	3.5	2.6	2.1	1.8	1.4	1.1
	30	F	F	0.087	11	6.5	5.2	4.3	3.2	2.6	2.2	1.7	1.3
	40	F	F	0.10	13	7.4	5.9	5.0	3.7	3.0	2.5	2.0	1.5
	50	F	VF	0.11	14	8.2	6.5	5.4	4.1	3.3	2.7	2.2	1.6
	60	F	VF	0.12	15	8.9	7.1	5.9	4.5	3.6	3.0	2.4	1.8
XR80015 XR110015 (100)	15	M	F	0.092	12	6.8	5.5	4.6	3.4	2.7	2.3	1.8	1.4
	20	M	F	0.11	14	8.2	6.5	5.4	4.1	3.3	2.7	2.2	1.6
	30	F	F	0.13	17	9.7	7.7	6.4	4.8	3.9	3.2	2.6	1.9
	40	F	F	0.15	19	11.1	8.9	7.4	5.6	4.5	3.7	3.0	2.2
	50	F	F	0.17	22	12.6	10.1	8.4	6.3	5.0	4.2	3.4	2.5
	60	F	F	0.18	23	13.4	10.7	8.9	6.7	5.3	4.5	3.6	2.7
XR8002 XR11002 (50)	15	M	M	0.12	15	8.9	7.1	5.9	4.5	3.6	3.0	2.4	1.8
	20	M	F	0.14	18	10.4	8.3	6.9	5.2	4.2	3.5	2.8	2.1
	30	M	F	0.17	22	12.6	10.1	8.4	6.3	5.0	4.2	3.4	2.5
	40	F	F	0.20	26	14.9	11.9	9.9	7.4	5.9	5.0	4.0	3.0
	50	F	F	0.22	28	16.3	13.1	10.9	8.2	6.5	5.4	4.4	3.3
	60	F	F	0.24	31	17.8	14.3	11.9	8.9	7.1	5.9	4.8	3.6
XR110025 (50)	15		M	0.15	19	11.1	8.9	7.4	5.6	4.5	3.7	3.0	2.2
	20		M	0.18	23	13.4	10.7	8.9	6.7	5.3	4.5	3.6	2.7
	30		F	0.22	28	16.3	13.1	10.9	8.2	6.5	5.4	4.4	3.3
	40		F	0.25	32	18.6	14.9	12.4	9.3	7.4	6.2	5.0	3.7
	50		F	0.28	36	21	16.6	13.9	10.4	8.3	6.9	5.5	4.2
	60		F	0.31	40	23	18.4	15.3	11.5	9.2	7.7	6.1	4.6
XR8003 XR11003 (50)	15	M	M	0.18	23	13.4	10.7	8.9	6.7	5.3	4.5	3.6	2.7
	20	M	M	0.21	27	15.6	12.5	10.4	7.8	6.2	5.2	4.2	3.1
	30	M	F	0.26	33	19.3	15.4	12.9	9.7	7.7	6.4	5.1	3.9
	40	M	F	0.30	38	22	17.8	14.9	11.1	8.9	7.4	5.9	4.5
	50	M	F	0.34	44	25	20	16.8	12.6	10.1	8.4	6.7	5.0
	60	F	F	0.37	47	27	22	18.3	13.7	11.0	9.2	7.3	5.5
XR8004 XR11004 (50)	15	C	M	0.24	31	17.8	14.3	11.9	8.9	7.1	5.9	4.8	3.6
	20	C	M	0.28	36	21	16.6	13.9	10.4	8.3	6.9	5.5	4.2
	30	M	M	0.35	45	26	21	17.3	13.0	10.4	8.7	6.9	5.2
	40	M	M	0.40	51	30	24	19.8	14.9	11.9	9.9	7.9	5.9
	50	M	F	0.45	58	33	27	22	16.7	13.4	11.1	8.9	6.7
	60	M	F	0.49	63	36	29	24	18.2	14.6	12.1	9.7	7.3

4.8.1 Selecting a Nozzle to Give Desired Spray Quality (Droplet Size)

In the previous exercise we considered selecting:

a) nozzle XR8003 or XR11003 at 30psi to give 0.26GPM or

b) nozzle XR8004 or XR11004 at 20psi to give 0.28GPM

Using the same table or the table on page 183 of the same catalogue, you can see:

a) an XR8003 at 30 psi gives a medium (yellow) spray quality

b) an XR8004 at 20 psi gives a coarse (blue) spray quality

c) an XR11003 at 30 psi gives a fine (orange) spray quality

d) an XR11004 at 20 psi gives a medium spray quality.

XR TeeJet® (XR) and XRC TeeJet® (XRC)

	PSI						
	15	20	25	30	40	50	60
XR8001	M	F	F	F	F	F	F
XR80015	M	M	M	F	F	F	F
XR8002	M	M	M	M	F	F	F
XR8003	M	M	M	M	M	M	F
XR8004	C	C	M	M	M	M	M
XR8005	C	C	C	C	M	M	M
XR8006	C	C	C	C	C	C	C
XR8008	VC	VC	VC	C	C	C	C
XR11001	F	F	F	F	F	VF	VF
XR110015	F	F	F	F	F	F	F
XR11002	M	F	F	F	F	F	F
XR110025	M	M	F	F	F	F	F
XR11003	M	M	M	F	F	F	F
XR11004	M	M	M	M	M	F	F
XR11005	M	M	M	M	M	M	F
XR11006	C	C	M	M	M	M	M
XR11008	C	C	C	C	C	M	M

4.9 Spray Classification and Target Uses

1. **Fine sprays** can enhance retention on the target and may be used for foliar acting weed control and cotyledon-stage weed control. If using fine spray droplets, careful attention must be paid to weather conditions. Do not use a fine spray for pesticides with a Warning or Danger rating, or when drift may cause problems near susceptible or sensitive areas.

2. **Medium sprays** are generally the best when leaves are the target. Medium sized droplets provide good foliar coverage without extensive losses to off-target drift.

3. **Coarse sprays** have a low risk of drift but should be used only where recommended because many of the larger droplets may bounce off of leaves.

Please note: Where trade names appear, no discrimination is intended and no endorsement in implied.4.9 Boom

Sprayer Calibration
(Use Clean Water)

Step 1. Check your tractor/sprayer speed

Formula:

$$MPH = \frac{\text{ft traveled}}{\text{sec traveled}} \times \frac{60}{88}$$

Your tractor sprayer speed:

$$MPH \quad \frac{\text{ft traveled}}{\text{sec traveled}} \times \frac{60}{88} = \_\_\_\_\_\_$$

Step 2. Record the inputs

	Your figures	*Example*
Nozzle type on your sprayer (all nozzles must be identical)	________	110 04 flat fan
Recommended application volume (from manufacturer's label)	________	20 GPA
Measured sprayer speed	________	4 mph
Nozzle spacing	________	20 inches

Step 3. Calculate the required nozzle output.

Formula:

$$GPM = \frac{\text{GPA} \times \text{mph} \times \text{Nozzle spacing}}{5940 \text{ (constant)}}$$

Example:

$$GPM = \frac{20 \times 4 \times 20}{5940} = \frac{1600}{5940} = .27 \text{ GPM}$$

Your figures:

$$GPM = \frac{\quad \times \quad \times \quad}{5940} = \frac{\quad}{5940} = \quad GPM$$

Step 4. Operate the sprayer

Set the correct pressure at the gauge using the pressure regulating valve.

Collect and measure the output of each nozzle for one minute.

The output of each nozzle should be the approximately the same as calculated in Step 3 above. Remember 128 fl. oz. in one gallon. If output has been calculated at 0.27 GPM then output is 128 multiplied by 0.27 = 34.5 fl. oz. in one minute.

Replace all nozzle tips that are more than 10% inaccurate.

4.10 Equipment for Weed Control in Orchards

Herbicides require good application technique for effective deposition without drift. Some of the commonly used herbicides can damage young trees and so great care must be taken. Drift has been a major concern for some years, off-target application wastes money, reduces deposition on the target plant, damages young trees, pollutes water courses and may cause nausea to other people.

4.10.1 Boom Applicators

A boom may be fitted either to the front of the tractor or be mid-mounted for spraying one side of the adjacent row. 20–30 gallons per acre are typical spray volumes.

The use of hoods and break-back devices are important. A hood will protect the branches from drift created by the small droplets being emitted from the conventional flat fan nozzle. A break-back device will protect the sprayer boom and nozzle from damage caused by inadvertently striking a trunk or trellis post etc. Break-back devices normally comprise a spring-loaded arm.

Correct nozzle selection is one of the most important yet inexpensive aspects of pesticide application. A nozzle's droplet size spectrum determines deposition and drift and is referred to as spray quality. Modern nozzle catalogues provide information on spray quality for each nozzle. When applying herbicides, we need to select a MEDIUM quality spray. Conventional flat fan nozzles produce droplets in the range of 10–450 microns. There are 25,000 microns in one inch. Drift is a major problem with droplets less than 150 microns.

Increasing the Volume Median Diameter (VMD) will certainly reduce drift, but too large a droplet (>300 microns) will bounce off the leaves to the ground, thus causing pollution, wasting money and resulting in less product on the target.

4.10.2 Herbicide Nozzles

4.10.2.1 Conventional Flat Fan Nozzles

Nozzles with 80 degree angle produce coarser droplets than a 110 degree nozzle at the same flow rate, but 80° nozzles require the boom to be set at 17–19 inches, whereas 110° nozzles can be set lower at 15–18 inches above the target. The lower the boom, the less chance of drift. Droplet size is fine to medium at 15–60 psi.

4.10.2.2 Pre-Orifice Flat Fan Nozzles

The design of this nozzle reduces the internal operating pressure compared with a conventional flat fan, resulting in coarser droplets (high pressure creates fine droplets, low pressure creates coarser droplets). Available as 80° or 110° nozzles. Droplet size is medium–coarse at 30–60 psi. Drift-guard is a well-known trade name.

4.10.2.3 Turbo-TeeJet

A turbulence chamber produces a wide-angle flat spray pattern of 150 degrees. Droplet size is medium–coarse at 15–90 psi. Nozzles can be set at 15–18 inches above the target.

4.10.2.4 Air Induction Nozzles

Air induction, air inclusion or venturi nozzles are flat fan nozzles where air is drawn into the nozzle through two holes in the nozzle side, mixing with the spray liquid. The emitted spray contains large droplets filled with air bubbles and virtually no fine, drift-prone droplets. The droplets explode on impact with leaves and produce similar coverage to conventional, finer sprays.

Air induction nozzles reduce drift even when operating at higher pressures of 80–90 psi. They are available at 110º fan angles, so boom height may need to be adjusted to 15–18 inches. The use of adjuvants will certainly help create bubbles. Air induction nozzles work very well for herbicide application; giving good deposition with no drift.
Boom manufacturers and distributors include: Phil Brown Welding Corp., Green Hoe Co. Inc., OESCO, Inc.

Nozzle manufacturers include: Albuz, Greenleaf, Hardi, Lechler, Tee Jet

4.10.3 Sensor-Controlled Applicators

Sensor-controlled pesticide applicators use optical sensors to determine where weeds are located. These sensors, coupled with a computer controller, regulate the spray nozzles and apply herbicides only when needed, thus considerably reducing herbicide use. A computer-controlled sensor detects chlorophyll in plants and then sends a signal to the appropriate spray nozzle, applying the herbicide directly to the weed. The operator calibrates the system to bare soil or pavement, allowing the computer to determine when there is a weed present. Sensor-controlled applicators are often mounted on ATVs, John Deere Gators, etc.; they can also be attached to tractors or trucks. Typically, this type of applicator can be used at speeds up to 10 mph. A complete sensor-controlled system consists of a chemical tank, pump, battery power, computer controller, optical sensors and spray nozzles.

4.10.3.1 Benefits of Sensor-Controlled Applicators:

- Reduced amount of herbicide applied
- Reduced potential for groundwater contamination
- Ability to apply herbicides in dark or light conditions

- If equipped with wind-deflecting shields, can reduce herbicide drift

Sensor Manufacturers/distributors include: Patchen/Ntech, OESCO, Zahm and Matson

4.10.4 Controlled Droplet Applicators (CDA)

Traditional flat fan nozzles produce a range of droplets, 10–450 microns; some drift, some roll off the leaves, others will adhere to the target leaves. A CDA herbicide applicator comprises an electrically-driven spinning disc under a large plastic hood or dome. The circumference of the disc has small teeth, which break up the liquid herbicide into droplets, of which 95% are the same size. The speed of the spinning disc dictates droplet size. As there are no large or small droplets in the CDA spectrum, all the droplets stick to the plant and so reduced rates can be applied, e.g. 1–8 GPA.

Various widths of hood or dome can be selected, and are fitted with break-back devices. Where the ground is rough, e.g., stones, then a bristle skirt maybe used. In young trees an optional plastic cover can be fitted over the bristle skirt.

CDA sprayers reduce the amount of water required, thus considerably improving spraying logistics. They are lightweight, relatively inexpensive and very maneuverable.

CDA sprayer Distributors include: BDI Machinery Sales, North-Eastern Equipment, Lakeview Harvesters, Rammelt & Co.

4.10.5 Flame Applicators

Most flame applicators burn liquid propane gas to create a flame with a temperature near 2000 F. The flame is applied directly to weeds with a hand-held wand or with boom-mounted torches attached to a tractor or ATV. The flame is applied to each weed for only a short period of time, usually about 1/10 of a second. The length of time the flame is applied depends on the age, size, and tenderness of the weed. The best timing is when weeds are 1 to 3 inches tall and typically in the spring and early summer. The flame causes cells to burst by boiling the water inside them. The weeds are not burned up, but by destroying cells, the plant is unable to transport water and continue photosynthesis, causing the weed to wilt and die. Flame applicators should only be used when there is little or no potential for setting fire to dry plant material. Beware of setting fire to trellis posts and poison ivy.

4.10.5.1 Benefits of Flame Applicators

- Non-chemical weed control method. No harmful drift
- No groundwater contamination
- No chemical exposure to workers

Manufacturer: Red Dragon

4.10.5.2 Online Resources

Cornell University Pesticide Application Technology
http://www.nysaes.cornell.edu/ent/faculty/landers/pestapp/
Information on various types of sprayers (air-blast, boom and knapsack etc) with links to most of the manufacturers of orchard, vineyard, turf and vegetable spraying equipment; plus information on sprayer calibration, nozzles, sprayer manufacturers, crop specific spraying sections with extension and research publications on sprayer technology.

Airblast sprayer nozzles, etc.

Delavan Ag Spray Products
www.delavanagspray.com/

GreenLeaf Technologies
(Turbodrop, Spraymax and Airmix)
www.turbodrop.com/
1-800-881-4832

Hardi
www.hardi-us.com/
563-386-1730

HyPro Global Spray Solutions (Albuz and AVI)
www.hypropumps.com/
1-800-424-9776

Lechler Agricultural
www.lechlerag.com/home.asp
1-800-7770-2926

TeeJet Technologies
www.teejet.com/
630-665-5000

Wilger Industries
www.wilger.net
877-968-7695

Equipment Dealers
BDI Machinery Sales, Macungie, PA
www.bdimachinery.net/
1-800-808-0454

Green Hoe Company Inc., Portland NY
www.greenhoecompany.com/
716-792-9433

Lakeview Harvesters, Ontario, Canada
www.lakeviewvineyardequipment.com/
1-866-677-4717

Northeastern Equipment Mattituck NY
www.northeasterneq.com/main.htm
1-631-765-3865

OESCO, Conway, MA
www.oescoinc.com
1-800-634-5557

Patchen Weedseeker:
http://www.ntechindustries.com/
1-888-728-2436

Phil Brown Welding Corp.
616-784-3046

Rammelt & Sons
http://www.rammeltandsons.com/contactus.htm
1-800-388-3802

Red Dragon Flame Weeder
http://www.flameeng.com/
1-888-388-6724

Rittenhouse, Ontario, Canada
www.rittenhouse.ca
1-800-461-1041

4.11 Decontaminating and Storing Crop Sprayers

Sprayers must be thoroughly cleaned inside and out after use. Ideally, a sprayer should be cleaned at the end of each day and especially before switching to a different pesticide. Pesticide residues left on the outside of the sprayer can cause operator contamination. Residues on the inside of the tank or left over pesticides trapped inside the sprayer plumbing system can contaminate the operator and possibly lead to crop damage. Growers should be concerned about this, especially if they are using one sprayer to apply different chemicals to different crops. In some cases, only a small amount of a pesticide remaining in the sprayer can cause significant crop damage or lead to unacceptable residues on a crop. Crop contamination can even occur several months after a sprayer has not been properly cleaned. Where an airblast sprayer is used to spray different fruit crops, residue left in the tank can cross contaminate another fruit crop, resulting in rejection by the processor.

Sprayers can also retain tremendous amounts of pesticide solution. Depending on the size and design of the sprayer, there can be nearly 6 gallons of solution left in an airblast sprayer's plumbing. As illustrated in the table below, research conducted on boom sprayers has shown that, depending on the spray tank size, the total chemical solution retained in the sprayer ranged from just under 3 gallons to over 12 gallons. The parts that retained the most chemical solution are the chemical induction bowl, the booms, the tank and the pump and its related piping.

Tests have shown that triple rinsing the spray tank is better than using just one single rinse. For example, using 100 gallons of clean water in one single rinse to clean a 100-gallon sprayer tank reduced the concentration of the original spray solution from 100% to 5% both in the tank and at the nozzle. If triple rinsing was performed using 33 gallons of clean water per rinse, a concentration of 0.2% to 0.5% was gained. The aim is for maximum dilution with minimal use of water. The following table illustrates how triple rinsing reduces the pesticide concentration at the nozzle and the tank drain.

Concentration of Pesticide in Rinse Water

Rinse Number	Sample Location	Percent Concentration
1	Nozzle	5.5
	Tank Drain	4.8
2	Nozzle	1
	Tank Drain	1
3	Nozzle	0.2
	Tank Drain	0.2

Source: Nilsson, E., Hagenwall H. og Jorgensen L.

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Quantity and Location of Chemical Remnants in Crop Sprayers (*in gallons*)

Location	Sprayer Size: *159 Gallons- 39 foot boom*	*212 Gallons - 39 foot boom*	*396 Gallons - 59 foot boom*
Tank	.50	1.32	4.57
Pump and associated piping	.40	.85	2.22
Pressure agitation	.02	.16	.27
Manifold	.04	.16	.27
Filter relief valve	NA	.15	.23
Chemical induction bowl	1.16	1.69	NA
Total without boom	**2.12**	**4.33**	**7.56**
Booms	.50	2.32	4.76
Total with booms	**2.62**	**6.65**	**12.32**

Adapted from "Quantity and Location of Chemical Remnants within a Range of Field Crop Sprayers by S.E. Cooper. Available: www.hardiinternational.com/Agronomy/Education_Material/pdf/08a.pdf

Before rinsing a sprayer, read the sprayer manufacturer's instructions for specific guidance on the best methods for cleaning your equipment. Also consult the pesticide label for any special cleaning instructions. When cleaning spray equipment, you should use the protective clothing listed on the pesticide label. Sprayer cleaning should be done so that rinse water does not enter any waterway, field drainage system, or well. Ideally, sprayer rinsate should be applied to a labeled crop rather than dumped at the cleaning location. If rinsing needs to be done at the mixing/loading site, it must be done on an impervious surface. All contaminated rinse water must be trapped and either used to mix another load of the same pesticide at the label recommended rates or disposed of at an approved pesticide waste handling facility

4.11.1 Reducing Cleaning Problems

The need for cleaning can be reduced by good planning and equipment maintenance. The following are suggestions to help reduce cleaning needs:

- Carefully plan how much pesticide to mix so that all mixed pesticides are used up when you are finished with the field.
- Be sure that the sprayer is clean before you use it.
- Make sure all parts of the sprayer are in good condition. Corroded, cavitated or pitted surfaces are prime areas for pesticide residue to hide. Replace any worn parts.
- Mix the chemicals in the correct order. Some chemicals, when mixed in the wrong order, can actually become more difficult to remove from the equipment. Consult the pesticide label for the proper mixing order.
- Follow any label instructions for cleaning spray equipment.
- Be sure that cleaning solutions contact ALL equipment surfaces.
- Remove and clean filters, strainers and nozzle screens separately from the rest of the sprayer.

4.11.2 Sprayer Cleansers

Several sprayer cleansers are commercially available. These cleansers should be selected based on the pesticide formulation used. Specific recommendations can be found on the pesticide label, by contacting the pesticide manufacturer or through the label or manufacturer of the cleaning agent you wish to use. Some available cleansers are listed in the table on the next page. Household detergents, such as laundry soaps and household ammonia, can also be used, but they may not adequately deactivate and solubalize the pesticides for effective cleaning. Chlorine bleach solutions should not be used. Cleaning agents can be used to wash both the inside and outside of the sprayer. When using commercial cleansers, follow the product's instructions for the best results.

4.11.3 Tank Rinse Systems

(Low-Volume Tank Rinsing)

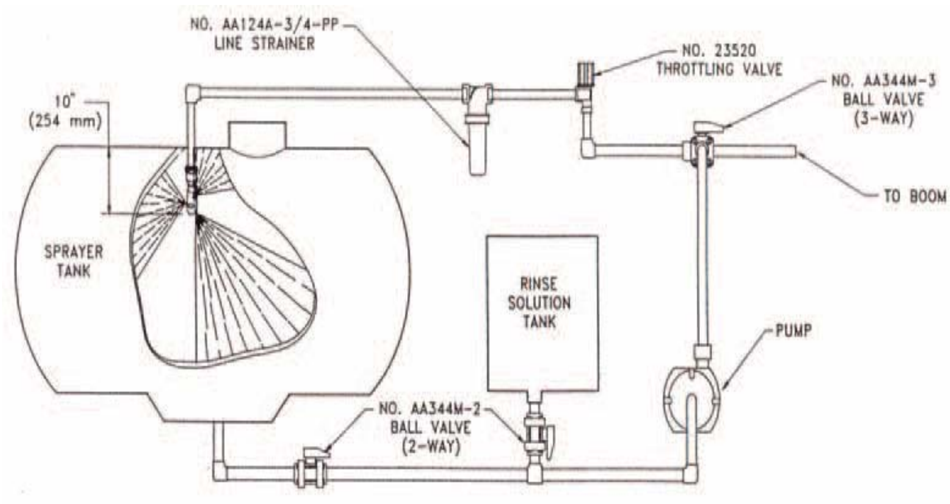
Tank rinse systems consist of a clean water supply tank mounted to the sprayer and one or more rotating discs or nozzles mounted inside the main sprayer tank. Water is pumped from the clean water tank to the rinse nozzles where the water is sprayed around the inside of the spray tank. These systems are designed for in-field rinsing of the sprayer so that the tank washings can be applied to the field and reduce the amount of time spent traveling to and from the farmyard.

A tank rinse system can be purchased as an option on some sprayers or as an add-on kit. Rinse systems can also be made from readily available parts and installed on the sprayer. A sample rinse system layout is shown below. A typical rinse system uses 360-degree tank wash nozzles mounted in the top of the tank. These nozzles are available in flow rates of 10 gallons of water per minute at 20 psi up to 20 GPM at 50 psi. If a spray tank has baffles, at least one rinse nozzle per compartment should be provided. In any case, a sufficient number of rinse nozzles should be installed to provide enough rinse water to contact the entire tank interior.

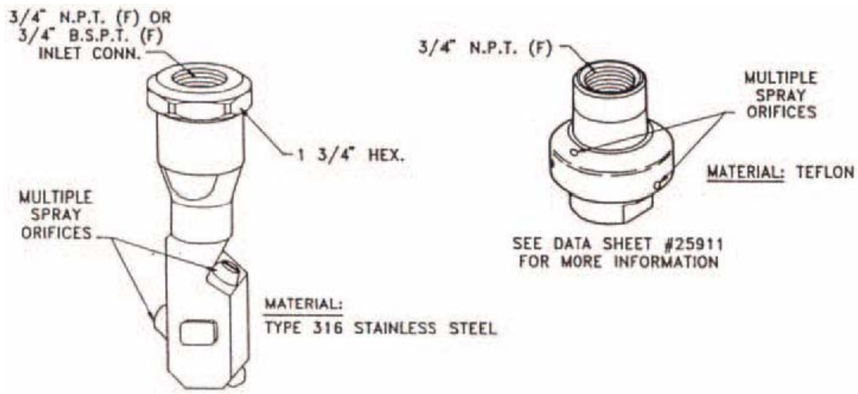
Commercially Available Sprayer Cleansers

Product	Supplier
Protank Cleaner	Agriliance P.O. Box 64089 St. Paul, MN 55164-0089 Phone: (651) 451-5151 Web: www.agriliance.com
All Clear Tank Decontaminator	UAP Loveland Industries, Inc. PO Box 1289 Greeley, CO 80632 Phone: 970-356-8920 Fax: 970-356-8926 Email: webmaster@lovelandindustries.com

Product	Supplier
Wipe-Out	Helena Chemical Company 225 Schilling Blvd. Collierville, TN 38017 Web: www.helenachemical.com
Ag Chem Tank Cleaner	Ag Chem Equipment Co. Ag-Chem Division 202 Industrial Park Jackson, MN 56143 Phone: 800-760-8800 Web: www.sprayparts.com



Sample layout of a sprayer rinse system



Two types of 360-degree tank rinse nozzles

A 50 to 100 gallon tank is plumbed into the sprayer plumbing system to provide the clean water. This tank should be permanently marked "Clean Water Only" so that only clean water is placed in the tank, reducing the chance for contamination of the rinse system. The tank should be mounted above the pump in order to aid in priming the pump. Ideally, the tank should be mounted on the sprayer.

When using tank rinse systems, you may want to check the pesticide label or with the chemical manufacturer to be sure that low-volume rinsing is suitable for the products you're using. Also, during the rinse process, be sure to open and close the pressure valve and other control valves on the sprayer to ensure that any chemical that may be trapped in the valve is rinsed out, further reducing the chance for contamination of future pesticide mixes. To obtain the best results, practice using the rinse system by placing spray marker dye or food coloring in the spray tank. Using the rinse system, run three rinse cycles, making sure the water discharged from the nozzles is completely clear by the end of the third rinse.

4.11.4 Cleaning the Sprayer

The pesticide applicator should try to keep the volume of tank wash water produced to a minimum. Ideally a tank rinse system should be used. There are two levels of sprayer cleaning:

- where the same or similar products are to be used on consecutive occasions or
- where the type of product is changed for another or at the end of the season.

4.11.4.1 Cleaning where Similar Products are Used

Reminder: *Before cleaning application equipment, remember to wear the protective clothing listed on the pesticide label.*

1. Be sure that all mixed pesticides have been used up from the sprayer or removed and disposed of properly.
2. Flush sprayer with clean water, making sure to wash all inside surfaces of the tank, including the underside of the lid. Use of a tank rinse system is preferred so that rinsing can be done in the field where the rinse water can be applied to the crop.
3. If a tank rinse system is not available, fill the spray tank about half full with clean water and flush the system for at least 5 minutes using both agitation and spraying. Be sure to open and close any control valves during the rinse process. The rinsate should be applied to the crop at labeled rates. Repeat this procedure two more times.

4. Hose down the outside of the sprayer making sure to reach all parts, scrubbing if necessary.
5. Remove suction, main and in-line filter elements and wash them thoroughly in clean water using a soft bristle brush. Put the filters back on the sprayer when clean.
6. Remove the nozzles, nozzle screens and nozzle bar end caps (if used) and wash them thoroughly in clean water with the appropriate cleanser and rinse. Remember to use a soft bristle brush, such as an old toothbrush, when cleaning nozzle parts.
7. Partly fill the sprayer with clean water and run the sprayer to flush out all parts.
8. Reinstall nozzles and nozzle screens.
9. Hose down the outside of the sprayer once again.

4.11.4.2 Cleaning where Product Type is Changed

This procedure should also be followed at the end of a season or before sprayer maintenance. **Remember to wear the protective clothing listed on the pesticide label.**

Follow steps 1–6 above.

7. Refill the tank with clean water, adding any detergent recommended by the pesticide manufacturer. Remember, use commercial cleansers according to their directions. Agitate the solution and pump it through the sprayer plumbing system.
8. Discharge the cleaning solution from the sprayer through the plumbing system, making sure to drain the system as thoroughly as possible.
9. Rinse the sprayer and flush the plumbing system with clean water.
10. Inspect the sprayer for deposits that may remain in the tank or plumbing system. If any remain, use some of the cleaning solution and scrub the problem spots. Rinse the sprayer out completely.
11. Repeat steps 7 to 9.
12. Hose down the outside of the tractor and sprayer, scrubbing if necessary.
13. If changing from one type of pesticide to another, refit nozzles, filters and other parts that may have been removed in the cleaning process.
14. When cleaning and preparing the sprayer at the end of the season, safely store nozzles and filters to keep them clean and damage-free. Leave valves open and the tank lid loosely closed.

Tank Rinse Nozzle Suppliers include: Spraying Systems (TeeJet), Delavan

4.11.5 Disposal of Pesticide Waste

The safe disposal of pesticide waste is a serious responsibility for growers and spraying contractors. It is important, therefore, that everything should be done to keep to a minimum the amount of waste generated.

Pesticide waste is of four types:

- ☐ Concentrated products.
- ☐ Diluted pesticides, including washings.
- ☐ Empty containers.
- ☐ Contaminated clothing and other materials.

Caution

All mounted sprayers tend to be unstable when removed from their tractors. Make sure they are safely chocked before leaving them.

4.11.6 Mechanical Maintenance

Lubrication must be done at the intervals specified by the sprayer manufacturer. The following components must be checked daily when a sprayer is in use:

- ☐ Pump crankshaft oil level.
- ☐ Fan drive gearbox oil level.
- ☐ Fan drive shaft bearings.
- ☐ Agitator shaft bearings.
- ☐ PTO shaft bearings.
- ☐ PTO shaft safety cover.
- ☐ Wheels, wheel bearings and tire inflation.
- ☐ Rotary atomizers for damage and lubrication.

Occasionally check the spray liquid system for leaks and signs of damage or wear. Any needed repairs should be done as soon as possible.

4.11.7 Storage of Sprayers

Sprayers should be stored carefully after use. Manufacturers' specific instructions should be followed but in their absence use the following general guidelines.

1. Thoroughly wash the sprayer inside and out with water, followed by a solution of detergent and water, followed by water. Drain thoroughly. Allow the access of air to all parts of the sprayer system. A more thorough decontamination routine is outlined above.
2. Inspect filters, nozzles, hoses and all other components and order all necessary spares.
3. Pay particular attention to the pump. Inspect rollers or diaphragms (if fitted) and valves and order necessary spares.
4. Check the soundness of all mechanical components, particularly booms and boom hinges, and the wheels.

5. Store sprayer under cover, taking care to prevent dirt and moisture affecting tank or working parts.

4.11.8 References

DuPont Agricultural Products. 1995. A Guide to Application Equipment Cleanout for DuPont Sulfonylurea Herbicides. DuPont Agricultural Products.

Hardi International web site: www.hardi-international.com

Harrison, Scott and Hock, Winand. (undated) Agrichemical Fact Sheet #9 - Options for In-field Pesticide Sprayer Rinsing and Clean Water Utilization. Penn State Cooperative Extension.

Johnson, Bill, et al. 1997. Cleaning Field Sprayers to Avoid Crop Injury, Fact Sheet G 4852. MU Extension, University of Missouri - Columbia.

Peterson, Dallas E., Kuhlman, Dennis K., and Devlin, Daniel L. 1998. Cleaning Field Sprayers. Kansas State University Department of Agronomy.

4.12 Homeland Security

The following examples of activity relating to spraying equipment may be of possible concern to law enforcement.

- The unexplained loss or theft or attempted theft of equipment or separate machine components used in agricultural spraying or mosquito extermination (i.e. mist blowers, tanks, axial or centrifugal fans, diaphragm pumps, nozzles, spouts, pressure regulators, etc).
- Inquiries from unknown persons as to the purchase or operation of spraying equipment; approach from a previously unknown customer whose identity is not clear; a customer's use of evasive responses.
- Unusual inquiries about modifying spraying equipment.
- Requests for information or for purchase of pesticides that may be harmful to humans.
- Individual making observations of your spraying operations, who when approached, deliberately leave to avoid questioning.
- A request to purchase spraying machinery by someone who does not appear to have previous experience in such work or a connection to the agricultural industry or mosquito extermination effort (i.e. unable to answer basic questions about intended application and range, water volume rates, desired nozzle output, spray pattern, acreage, crops, soil composition, etc).
- A request to ship spraying equipment to an area or region not normally associated with spraying operations.
- A customer's reluctance to provide information on the locations of the plant or place where the equipment will be stored.

4.13 Going Spraying!

Mixing Procedures

Safety and the Law

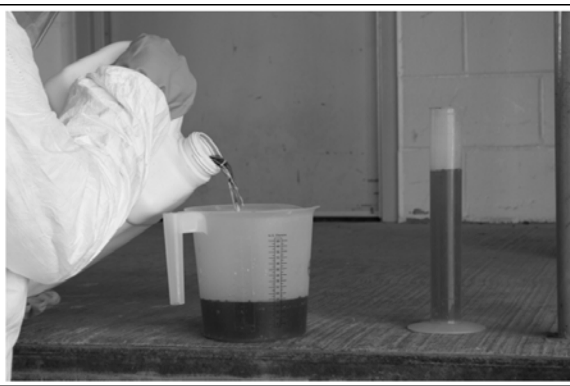
- Always remain alert. Pesticides are potentially dangerous to the operator and to the environment.
- Tractors and sprayers are dangerous machines that require knowledge and care to use safely.
- Always follow Federal and State laws concerning operator licensing and handling, application and disposal of pesticides.

- Always read the label for detailed application instructions.
- Keep a complete record of products, dosage, spray volumes, and application condition.
- The seven P's of machinery management:
  Proper Prior Planning Prevents Poor Performance

- Set tank on level ground.
- Fill as per label directions. If not specified, fill the tank half full with clean water.
- Prime the pump with water, if needed.

ALWAYS

- Make sure there is no direct connection between the water source and sprayer tank. Direct connections can contaminate the water supply by allowing chemicals to siphon backwards.
- Use a strainer when using water from a stream or pond.



- When opening a package, avoid using an "implement"; if used, decontaminate after use.
- Accurately measure the calculated amount of product.
  - △ Weigh solid formulations, and measure out liquid formulations, unless they come in pre-weighed packages appropriate for the spraying area.
- Handle water soluble packages according to directions. Keep packs dry and do not force open the packs.

- Avoid splashing and "glugging" of liquid formulations.
- Always add concentrated pesticides to a partially filled tank.
- If adding more than one product, do so separately and in the recommended order. **NEVER mix products together in their concentrated forms**
- If available, add product through a low-level induction bowl or through a suction probe.
- If not available, add pesticides through the tank filter basket, except for soluble packs and some water dispersible granule formulations. Some wettable powders may need to be premixed.

- If foaming is likely:
  - △ Fill the tank three-quarters full of water and use gentle agitation.
  - △ Add the pesticide.
  - △ Add the surfactant.
  - △ Continue to use gentle agitation until filling is finished.
- Do not add water from a height.

- Triple rinse pesticide containers with clean water and put washings into the tank.
- Rinse off any pesticides spilled on the sprayer or container, and avoid contaminating the surroundings or yourself.

- Fill tank to the correct level and agitate while filling. Continue agitating while driving to the field and while spraying unless instructions advise otherwise. If spraying is delayed, agitate thoroughly just before use.

- Rinse impermeable protective clothing (rubber boots, gloves, etc.) with clean water after use.

- Remove other protective clothing and store before getting into tractor cab.

- Seal unused chemicals and store in a safe location.