CHAPTER 5

Pesticide Management

Pesticide Safety

Toxicity of Pesticides: All pesticides must be toxic, or poisonous, to kill the pests they are intended to control. Because pesticides are toxic, they are potentially hazardous to humans and animals as well. Since pesticide toxicity varies widely, persons who use pesticides must have a general knowledge of the relative toxicity of the products being used.

The toxicity of a particular pesticide is determined by subjecting test animals (usually rats, mice, rabbits, and dogs) to different dosages of the active ingredient in a pesticide product. The active ingredient is the toxic portion of the pesticide formulation.

The toxicity of each active ingredient is determined by at least two methods: oral toxicity, by feeding the chemical to test animals; and dermal toxicity, by exposing the skin to the chemical and measuring its absorption through the skin into the bloodstream. Toxicity is usually expressed at LD_{50} (lethal dose 50), or the dose that kills 50 percent of the test animals.

All pesticide labels have important signal words. Highly toxic pesticides have the words "DANGER-POISON" on the label plus skull and crossbones. Moderately toxic pesticides have the word "WARNING" on the label, while the least toxic materials have the signal word "CAUTION." Table 9 shows the toxicity ratings and the amounts of pesticide that could be injurious or lethal to people. All products bear the statement "KEEP OUT OF REACH OF CHILDREN."

Pesticide Applicator Certification

The EPA has designated a number of fruit pesticides as "Restricted-Use Pesticides." Growers who wish to use these restricted materials must be certified as private applicators. A fruit grower can be certified as a private applicator by attending training sessions conducted by the Cooperative Extension Service in each state. Applicators must learn and understand labels and labeling; safety factors, including employee safety; potential environmental concerns; identification of common pests encountered; pesticides and their usage; proper equipment use; application techniques; and applicable state and federal regulations. County staff members usually conduct these training meetings. A test usually may be taken in place of the training. Contact your county Extension office for information.

Re-entry times: All pesticide labels specify the minimum re-entry interval (REI) after application. Workers not wearing protective clothing are restricted from entering sprayed fields until the longest re-entry time of the pesticides that were applied has expired. Check the "Agricultural Use Requirements" section of the pesticide label for the minimum re-entry time.

Table 9. Oral, dermal, and inhalation toxicity ratings of pesticides.

Toxicity rating	Signal words	Oral LD_{50} (mg/kg)	Dermal LD_{50} (mg/kg)	Lethal oral dose, 150-pound person
High	Danger-Poison (skull and crossbones)	0-50	0-200	few drops to 1 teaspoon
Moderate	Warning	50-500	200-2,000	1 teaspoon to 1 ounce (2 tablespoons)
Low	Caution	500-5,000	2,000-20,000	1 ounce to 1 pint, or 2 pounds
Very low	Caution	5,000+	20,000+	1 pint or more, or 2 pounds or more

Safe Storage of Pesticides

- Store pesticides in a clean, cool, dry, well-ventilated building. Keep the building locked so children, untrained persons, and animals cannot come in contact with the pesticides. Mark the storage facility with an appropriate warning sign.
- The area should be equipped with absorbent materials such as absorbent clay, sawdust, paper, or kitty litter. Other dedicated equipment should include a fire extinguisher (ABC rated), a shovel, broom, dustpan, detergent, hand cleaner, and water.
- Never store herbicides with other pesticides; the danger of cross-contamination is too great.
- Do not store pesticides where food, water, feed, seeds, fertilizers, or pesticide safety equipment (such as respirators) can become contaminated.
- Emulsifiable material should not be subjected to freezing temperatures. Freezing temperatures will destroy the emulsion, resulting in loss of effectiveness, and may cause serious plant injury.
- Check containers frequently for leaks and breaks.
- Clean up spilled chemicals promptly and properly. If the spill is large enough, inform your state and local emergency response office. Dispose of broken or damaged containers and any pesticide waste in an approved and safe manner.
- Keep an inventory of all chemicals. Mark each container with the year of purchase. Do not remove labels.
- Inform your local fire department and emergency response office of any agricultural chemicals (including fertilizers) stored in large quantity. Conform with federal and state regulations concerning reportable quantities of hazardous materials.
- Store all pesticides in their original containers.
- READ THE LABEL for specific storage instructions and precautions.

Safe Pesticide Use

- READ THE LABEL BEFORE USING PESTICIDES. *Use pesticides only when necessary and only at the recommended dosages and times* to keep residues within the tolerances set by law.
- USE THE RIGHT PESTICIDE FOR THE JOB! Mistakes in using the wrong material can be costly.
- Avoid spray drift to other crops and nontarget animals. Cover food and water containers in livestock areas. Protect beehives.
- Bathe and change clothing after applying pesticides. Wash clothing after each day's use.
- Do not contaminate the environment with pesticides.
- Use proper protective equipment according to instructions on the label. Never eat, drink, or smoke while applying pesticides.
- Avoid spilling spray materials on skin or clothing. If an accident occurs, wash immediately with soap and water.
- If pesticide poisoning is suspected, show the physician the label from the material suspected of causing the poisoning. The physician can contact a Poison Control Center for complete treatment information.
- Notify workers of the application and post-application information in accordance with the Worker Protection Standards.

Table 10. Gallonage of dilute spray per acre required to provide equivalent coverage for mature trees of different sizes and spacing.

Distance between Rows (feet)	Tree Height (feet)	Tree Width (feet)	Maximum Tree Volume/Acre (1,000 Cubic Feet)[a]	Maximum Dilute Spray (Gallons per Acre)[b]
30	20	15	436	300
26	16	12	354	225
24	14	10	254	180
22	14	10	272	200
20	12	10	261	185
18	10	10	242	175
16	8	8	174	125
14	6	8	149	105
12	6	6	131	90

a Maximum tree volume/acre = tree width x tree height x running feet of row per acre. Running feet of row/acre = 43,560 divided by the distance between rows.
b Minimum dilute gallons/acre = approximately 0.7 gallons/1,000 cubic feet of tree volume.

Personal Protective Equipment (PPE): Every pesticide label provides a specific description of the Personal Protective Equipment required during mixing, loading, application, and cleanup of that pesticide as well as for early entry that requires contact with anything that has been treated.

Pre-harvest Interval (PHI): The pre-harvest interval is the minimum amount of time required between application and harvest for specific crops. This time is indicated on the pesticide label. Some pesticides may allow the treated crop to be harvested the same day. Failure to abide by the pre-harvest interval may result in illegal pesticide residue levels.

Spraying the Orchard: Trees are sprayed with insecticides, fungicides, bactericides, growth regulators, and nutrient solutions in many different formulations and concentrations and at various stages of tree development. The principal target in tree spraying may be the foliage, the blossoms, the fruit, the woody surfaces, or all of these components. Obviously, the equipment and methods used for such a diverse spraying program must be versatile, and the equipment must be properly calibrated for each type of application to produce the desired results.

Dilute Spraying: During the early development of orchard application methods, trees were sprayed with gallonages sufficient to wet the target surfaces to the point of runoff (160 to 400 gallons per acre [GPA]). Spraying to the point of runoff is still the standard dilute application. Recommended rates for application of pesticides were developed on this dilute basis. Most recommendations required adding specific amounts of pesticide per 100 gallons of water for effective pest control. The GPA required for dilute spraying vary greatly, depending on the size and growth stage of the trees. Table 10 lists the gallons of dilute spray per acre required to provide equivalent coverage for mature trees of different sizes and spacings. Dilute is considered 1x concentration.

Growth regulators may be applied by high-pressure hand-guns or by air-blast sprayers, either dilute or low-volume. Low-volume application may be more risky because any mistakes in concentration are magnified.

Read the growth regulator label for suggestions on application methods. Some labels suggest dilute sprays with full coverage, whereas others suggest a specific amount of chemical in a specific amount of water per acre.

Low-volume Spraying: Low-volume, or concentrate, spraying refers to the use of less water per acre in applying pesticides. In low-volume spraying, the volume of water applied per acre is reduced in proportion to the increased concentration used. Thus, if a 3x concentration is used, apply only one-third the water per acre that would be used in dilute spraying.

Table 11. Gallons of spray per acre (approximate) for various concentrates.

	lx	2x	3x	4x	5x	6x	7x	8x	9x	l0x
Apples	300	150	100	75	60	50	45	38	33	30
Peaches	200	100	67	50	40	33	29	25	22	20
Percent water savings over dilute		50%	67%	75%	80%	84%	86%	88%	89%	90%
		GREATEST SAVINGS					DIMINISHED SAVINGS			

Low-volume sprays must be applied with air-blast sprayers which use a high-velocity airstream to distribute the spray mixture. Most conventional air-blast sprayers can be used to apply spray mixtures up to 6x concentration. Sprayers specifically designed for ultra low-volume application should be used for applications at 10x or greater.

Using low-volume sprays requires less labor, less water, less time, and fewer refills than 1x or dilute mixtures. However, savings in gallonage and application cost decrease most rapidly down to about 50 gallons of water per acre. Below that, the savings may not be worth the additional risk of proper application and problems with wind. Table 11 illustrates an 80 percent savings of water at 5x but only an additional 10 percent savings by increasing the concentrate to 10x.

Following are some precautions in the use of low-volume pesticide or growth regulator applications:

1. Use extreme care in calibrating the sprayer and maintaining a constant sprayer speed. As gallonage is decreased, errors become much more critical.
2. Choose calm, yet good drying conditions for spraying. This may mean spraying at night or early in the morning. Good coverage cannot be achieved in windy weather (over 5 mph).
3. Prune trees well to a very open canopy for spray penetration. Spray droplets will not penetrate large, thick trees.
4. Choose pesticide formulations that will mix satisfactorily. Pay careful attention to increased operator hazards and drift problems.

Tree Row Volume Spraying: Tree row volume (TRV) is a method of determining the dilute (1x) volume of spray solution necessary to cover the entire tree surface. This is an objective method of determining the differences in spray volume required for different tree size and age.

With the TRV method, the volume of dilute spray needed per acre can be easily calculated for each orchard based on tree age, size, amount of pruning, row spacing, etc. To determine the TRV, the between-row spacing, maximum tree height, and cross-row limb spread of trees must be accurately measured. See the step-by-step procedure below.

The TRV method can also be used to determine the pesticide rate for an orchard. Calculate the TRV gallonage for the orchard. Multiply this gallonage by the recommended dilute pesticide rate per 100 gallons to determine the rate of pesticide for dilute application. For example, a fungicide is recommended at 2.0 lb/100 gal. and is to be applied in an orchard with a TRV gallonage base of 400 gal./acre.

Therefore, the per acre rate for this pesticide is:
2 lb/100 gal. x 400 gal./acre = 8 lb/acre

To determine the rate of fungicide or insecticide per acre when spraying low volume (3x or greater), first calculate the *dilute* TRV gallonage. Multiply this gallonage by 0.75 to obtain a *concentrate* TRV gallonage. Multiply this concentrate gallonage times the recommended dilute pesticide rate per 100 gal. to determine the rate of pesticide per acre for concentrate application. For example, a fungicide is recommended at 2.0 lb/100 gal. dilute and is to be applied at 5x in an orchard with a TRV base of 400 gal./acre. The rate of pesticide per acre is calculated as:

(TRV gallonage)
x (0.75)
x dilute pesticide rate/100 gal.
= concentrate pesticide application rate/acre

400 gal./acre x 0.75 x 2 lb/100 gal. = 6.0 lb/acre.

If the TRV base gallonage is less than 200 gal./acre, use 200 gal. to compute the pesticide application rate.

Table 12. Determining density factors using tree density estimates.

0.70 gal./1000 cu ft	Trees extremely open, light visible through entire tree, less than 15 scaffold limbs per tree or young tree.
0.75 gal./1000 cu ft	Trees very open, 18 to 21 scaffolds per tree, light penetration throughout tree, healthy spurs within tree canopy.
0.80 gal./1000 cu ft	Trees well pruned, adequate light in trees for healthy spurs throughout trunk and scaffold limbs, many holes in foliage where light can be seen through tree.
0.85 gal./1000 cu ft	Trees moderately well pruned, reasonable spur population within canopy, tree thick enough that light cannot be seen through bottom two-thirds of tree.
0.90 gal./1000 cu ft	Trees pruned minimally, spurs inside canopy are weak due to limited light, very few holes where light can be seen through the tree.
1.00 gal./1000 cu ft	Tree unpruned, extremely thick, no light visible anywhere through tree canopy, trees more than 20 ft high.

How to calculate tree row volume gallonage:

Step 1

Calculate feet of row/acre.

$$\frac{\text{43,560 sq ft/acre}}{\text{between-row spacing (ft)}} = \text{feet of row/acre.}$$

Step 2

Calculate cubic feet of TRV/acre.

Feet of row/acre (from Step 1)
x tree height (ft)
x cross-row limb spread (ft)
= cu ft of TRV/acre.

Step 3

Select density factor from Table 12.

Select one of the density factors that best indicates the canopy density of each separate orchard or block.

Step 4

Calculate TRV gallonage/acre.

$$\frac{\text{cu ft of TRV/acre (from Step 2)} \times \text{density (from Step 3)}}{1{,}000}$$

= gal. of dilute solution applied per acre
= TRV gal./acre.

Example

An orchard has rows spaced 20 ft apart, tree height is 14 ft, and cross-row limb spread is 12 ft. The tree density is 0.85.

Step 1

43,560 sq ft/20 ft
= 2,178 ft of row/acre.

Step 2

2,178 x 14 ft x 12 ft
= 365,904 cu ft TRV/acre.

Step 3

Density has been given as .85.

Step 4

(365,904 x .85)/1,000
= 311 TRV gal./acre.

Orchard Sprayer Calibration

Determining Sprayer Speed

The rate of travel needed for proper distribution of spray within and to the tree top can be determined by trial or by placing special water-sensitive paper patches in trees. In general, a travel speed of 0.5 to 3 miles per hour has proven to be satisfactory, depending on the size and density of the trees.

Before a sprayer can be calibrated, the travel speed must be determined in miles per hour (mph). Load the sprayer with clear water, and make a test run in the orchard to determine travel speed. Speed can be calculated by measuring the time required to travel any measured distance. The following formula can be used to determine travel speed:

$$\text{Speed (mph)} = \frac{\text{distance (ft)} \times 60}{\text{time (sec)} \times 88}$$

For example, if it requires 60 seconds to travel a measured distance of 176 ft, the travel speed is:

$$\text{mph} = \frac{176 \times 60}{60 \times 88} = 10{,}560 = 2 \text{ mph}$$

Another method for checking travel speed is to count the number of trees passed in 1 minute. Table 13 will help you determine travel speed (mph) with tree spacings from 10 to 30 ft.

Determining Nozzle Flow Rate

To select the correct nozzle and whirlplate sizes, the total gallons per minute (GPM) of output for each particular application is determined. To determine the GPM, it is necessary to know the travel speed of the sprayer (mph), the gallons per acre (GPA) to be applied (of total volume), and the spacing (W) between the rows of trees. Once these three variables are measured or selected, a simple equation can be used to calculate the GPM. This equation is for one side of the sprayer manifold only. Double the calculated answer if both sides of the sprayer are to be used. Once the nozzle and whirlplate combinations are determined, place the same size nozzles and whirlplates in both sides of the sprayer if both sides will be used.

Step 1

Calculate the total GPM required per side:

$$\text{GPM (per side)} = \frac{\text{GPA} \times \text{mph} \times W}{1{,}000}$$

GPM = gallons per minute (per side)
GPA = gallons per acre
mph = speed in miles per hour
W = spacing between rows of trees in feet

Example

You have decided to apply 80 gal. per acre while traveling 2 miles per hour, with rows spaced 25 ft apart. What would the gal. per min per side be?

$$\text{GPM (per side)} = \frac{80 \times 2 \times 25}{1{,}000} = \frac{4{,}000}{1{,}000} = 4 \text{ GPM}$$

Step 2

Select the correct nozzle-whirlplate combination and operating pressure. Air-blast sprayers normally use disc-core-type cone spray tips. This information can be acquired either from the sprayer manufacturer or from a nozzle manufacturer. The correct size nozzles and whirlplates can be selected by using a table which indicates the nozzle size and gallons per minute output at various pressures using specific whirlplates. These tables can be found in the sprayer manufacturer's literature or in nozzle catalogs.

The arrangement of nozzles in the sprayer manifold should be such that approximately two-thirds of the total flow comes from nozzles in the upper half of the manifold and one-third from nozzles in the lower half. This should be adjusted to provide uniform coverage throughout the tree. It should provide adequate penetration to the top and top center of the tree while avoiding excess application rate in the lower outside areas. This is especially important when applying growth regulator materials, such as chemical thinners.

Step 3

Install the nozzles in their proper outlets. Inspect all nozzles and outlets for foreign material, and determine that the sprayer is operating correctly. Nozzles are a very important part of the sprayer; if any defects or wear are showing in the nozzles, they should be replaced.

Table 13. Determination of speed for air-carrier sprayers for selected tree spacings.

Number of trees passed per minute	Tree spacing in the row (feet)									
	10	12	14	16	18	20	22	24	28	30
	Miles per hour									
2	-	-	-	0.4	0.4	0.5	0.5	0.6	0.6	0.7
3	-	-	0.5	0.5	0.6	0.7	0.8	0.8	1.0	1.0
4	-	0.5	0.6	0.7	0.7	0.9	1.0	1.1	1.3	1.4
5	0.6	0.7	0.8	0.9	1.0	1.1	1.3	1.4	1.6	1.7
6	0.7	0.8	1.0	1.1	1.2	1.4	1.5	1.6	1.9	2.1
8	0.9	1.1	1.3	1.5	1.6	1.8	2.0	2.2	2.6	2.7
10	1.1	1.4	1.6	1.8	2.0	2.3	2.5	2.7	3.2	3.4
12	1.4	1.6	1.9	2.2	2.4	2.7	3.0	3.3	3.8	4.1
16	1.8	2.2	2.5	2.9	3.3	3.6	4.0	4.4	5.1	5.5
20	2.3	2.7	3.2	3.6	4.1	4.5	5.0	5.5	6.4	6.8

Step 4

Measure the total GPM from all the nozzles selected in Step 2. Fill the sprayer tank to a graduated mark on the sight gauge. It should be at least half full. Prime the sprayer system, and check all the nozzles to make sure none are clogged or partially clogged. Record the exact amount of water in the spray tank. Bring the sprayer up to the desired pressure, and turn the nozzles on. Use a stopwatch to record the amount of time the sprayer is running. The sprayer should be operated for at least 3 minutes.

Example

The spray tank is filled to the 200-gal. level. It was predetermined that the nozzles selected would give a total gal. per min output of 8. The sprayer was operated for 5 minutes at 150 psi on the gauge. After the 5 minutes, the sight gauge was read and found to be at a level of 170 gal.

The actual output was 200 gal. (start)—170 gal. (stop) = 30 gal. per 5 min or 6 GPM. The calculated output, however, was 8 GPM.

When the actual output is different from the calculated output, adjustments can be made by changing the pressure when the difference is small. When the difference is large, you will need to change the nozzle sizes.

Repeat these calibration procedures whenever changes are made in the speed, gallons per acre, or row spacing. Periodically check the output from the nozzles during the spraying season. Remember, the effectiveness of the spray material is directly dependent on your skill as an operator.

Field test to confirm calculations:

GPA (gallons per acre)

$$= \frac{\text{Gal. sprayed x 43,560 sq ft x No. passes per row}}{\text{distance traveled (ft) x row width (ft)}}$$

Herbicide Sprayer Calibration

Herbicides used in the orchard must be applied carefully to obtain uniform application over the soil surface or over the vegetation to be controlled. Here is a suggested technique for calibrating the herbicide boom that is attached to the side of a tractor:

1. Clean sprayer and replace all worn or defective parts; fill tank with water.
2. Adjust pressure and speed of tractor for nozzle size and output using manufacturer's directions.
3. Check to confirm that nozzle delivery rates are uniform. Catch output from each nozzle for 30 seconds. Output from all nozzles should be uniform within 10 percent. If not, replace out-of-range nozzles. Nozzles should be re-checked at least once each season.
4. Refill spray tank and spray 1/4 acre (10,890 sq ft). Distance of travel will vary with boom coverage.

For example, a 6-foot boom must travel 1,815 feet to cover 1/4 acre.

$$\frac{\text{1/4 acre (10,890 sq ft)}}{\text{Boom width (6 ft)}} = \text{Distance (1,815 ft)}$$

5. Measure amount of water needed to refill the spray tank to the same level as before. This amount was applied to the 1/4 acre; thus, four times this amount is the gallonage of spray per acre. For example, if it required 10 gallons to spray the 1/4 acre, then the per acre gallonage would be 40.
6. Adjustment in gallonage may be made either by varying tractor speed or by changing nozzle size. Do not use changes in pressure to change gallonage since the nozzle pattern will be affected. Recalibrate after each adjustment.
7. Calculate acres covered by full tank of spray solution. Add required amount of herbicide for the total area sprayed.
8. Calibrate spray tank for less than full tanks so that small blocks can be sprayed without having an excess of spray material.
9. Some herbicide materials may cause slight differences in nozzle patterns and output. To increase accuracy, calibrate for each different herbicide or combination being used. To do this, as you apply a new herbicide to the orchard, observe closely the point at which the tank of spray is exhausted. If this differs substantially from the calculated point of ending, then adjust the gallonage accordingly.

Reducing Spray Drift

Herbicides may drift through the air from the point of application and cause injury at another location if contact is made with susceptible plants. Spray drift is a function of the wind speed, droplet size, height above the ground from which the spray was released, and herbicide volatility. Generally there is less wind just before sunrise, just after sunset, and during the night. Thus, these are usually the best periods for spray applications. Winds tend to be more gusty and turbulent from 2 p.m. to 4 p.m. As droplet size is reduced, spray drift increases, and as droplets fall, evaporation may take place, producing extremely small droplets or particles. Generally high pressures produce small droplets, and low pressures produce large droplets. Small nozzles usually produce small droplets. Droplets larger than 200 microns fall to the ground fairly rapidly, while those below 150 microns fall very slowly. The height above the ground from which the spray is released is important. The greater the height, the longer it takes for droplets to reach the ground. Furthermore, wind velocities tend to be lower closer to the ground. Herbicide volatility refers to the tendency of a herbicide to vaporize or produce fumes. Highly volatile herbicides can produce vapor drift. The amine and sodium salts formulations of 2,4-D have little or no volatility problems, while the ester formulations vary from low to high volatility. Fruit growers generally avoid the 2,4-D ester formulations because of the capacity of these materials to move great distances from the application point, particularly when temperatures are 80°F or higher.

Reduce spray drift by using lower pressures, larger nozzles, and less volatile herbicides and by spraying when there is little wind and temperatures are not too hot. Also, set the boom or nozzles as close to the ground as possible.