Information and Resources

Pesticide Application Equipment and Calibration

for Non-Agricultural Applicators

What is calibration?

- Adjustments you make to application equipment and the procedures you must follow so you know you're applying the correct amount of pesticide to a treatment area

When should you calibrate?

- Beginning of the season
- Anytime something changes that can affect the application (output rate, travel speed, nozzles, product, person making the application)

Tools needed for calibration

- Stopwatch
- Measuring tape, flags, flagging tape, stakes
- Pocket calculator, paper pencil
- Calibrated container, pressure gauge, flow meter for liquid applications
- Small scale, tarp, funnels or cups for granular applications

Getting started

- Read the label to determine application rates
- Determine size of area to be treated or the number and size of trees and shrubs
- Be sure equipment is clean
- Wear personal protective equipment (PPE)
- Use clean water
- Choose the correct type of equipment based on formulation type and application site

Liquid application equipment

- Parts of a sprayer
    - Tank (holds the pesticide mixture)
    - Pump (hand or motor-operated to move the pesticide from the tank to the nozzles)
    - Nozzles (affect application rate, determine droplet size, and spray pattern)
        - Materials: brass, stainless steel, aluminum and nickel-copper alloy, plastic, tungsten carbide and ceramic
        - Types: flat-fan, off-center flat-spray, even flat-spray, cone, solid stream, flood, broadcast
    - Hoses, wands
    - Larger applicators may have pressure regulators, fans, filter screens, control valves, booms, agitators

Liquid application equipment (continued)

- Hand-operated equipment
  - Trigger pump sprayers
  - Compressed air/gas sprayers
  - Backpack sprayers
  - Wick applicators
- Powered application equipment
  - Powered backpack sprayers
  - Low-pressure sprayers
  - Controlled droplet applicators (ultra-low volume (ULV) foggers)
  - High-pressure hydraulic sprayers

Dust and granule application equipment

- Hand-operated applicators (strapped at chest and operator turns a crank)
- Mechanically-driven applicators
  - Wheeled rotary applicators
  - Drop spreaders
- Powered applicators (backpack applicators powered by small gas engines)

Drench and injection for application of root-absorbed systemic insecticides

- Soil drenching
  - Measure pesticide in a bucket, dilute it, pour it onto soil around base of the tree trunk
- Soil injection
  - Pressurized soil injector (delivers pesticide to tree roots without runoff)
- Tree injection
  - Pressurized devices force pesticide into a tree
  - Self-contained devices that release pesticide slowly

Information and Resources

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Key resources:

Find your county extension office

- California: University of California Department of Agricultural and Natural Resources (http://ucanr.edu/County_Offices/)
- Other states: National Pesticide Information Center (http://npic.orst.edu/countyext.htm)

Pest identification and management methods

- UC Statewide IPM Program (www.ipm.ucanr.edu/)
- UC Weed Research and Information Center (http://wric.ucdavis.edu)

Information about pesticide products and safety

- California Department of Pesticide Regulation (www.cdpr.ca.gov/)
- U.S. Environmental Protection Agency (http://www.epa.gov/pesticides/)
- USDA Agricultural Research Service (www.ars.usda.gov)
- National Pesticide Information Center (http://npic.orst.edu/gen.htm)
- Pesticides and Urban Water Quality (http://www.ipm.ucanr.edu/WATER/U/index.html)
- WaterTOX water-related risks of pesticides (http://www.ipm.ucanr.edu/TOX/simplewatertox.html)
- EXTOXNET (http://extoxnet.orst.edu/)
- Pesticide Wise (www.pw.ucr.edu)

Laws and Regulations

- DPR regulations in the California Code of Regulations (CCR) http://www.cdpr.ca.gov/docs/legbills/regshome.htm

Publications

- O'Connor-Marer, P.J. 2000. The Safe and Effective Use of Pesticides Second Edition. Oakland: Univ. Calif. Div. Agric. Nat. Res. Publ 3324. http://www.ipm.ucanr.edu/IPMPROJECT/ADS/manual_safeeffectiveuse.html
- O'Connor-Marer, P.J. 2006. Landscape Maintenance Pest Control. Oakland: Univ. Calif. Div. Agric. Nat. Res. Publ 3493. http://www.ipm.ucanr.edu/IPMPROJECT/ADS/manual_landscapemaintenancepc.html

Helpful Conversion Factors*

Pesticide Application Equipment and Calibration

for Non-Agricultural Applicators

Standard Measure	Metric Conversions
Length 1 ft = 12 in 1 yd = 3 ft 1 mi = 5,280 ft	**Length** 1 in = 25.4 mm = 2.54 cm 1 ft = 304.8 mm = 30.48 cm 1 yd = 914.4 mm = 91.44 cm = 0.914 m 1 mi = 1,609 m = 1.61 km 1 mm = 0.03937 in 1 cm = 0.394 in = 0.0328 ft 1 m = 39.37 in = 3.281 ft 1 km = 3,281 ft = 0.6214 mi
Area 1 sq in = 0.007 sq ft 1 sq ft = 144 sq in = 0.000023 ac 1 sq yd = 1,296 sq in = 9 sq ft 1 ac = 43,560 sq ft = 4,840 sq yd	**Area** 1 sq in = 6.45 sq cm 1 sq ft = 929 sq cm 1 sq yd = 8,361 sq cm = 0.8361 sq m 1 ac = 4,050 sq m = 0.405 h 1 sq cm = 0.155 sq in 1 sq m = 1,550 sq in = 10.76 sq ft 1 h = 107,600 sq ft = 2.47 ac

* Reproduced from *The Safe and Effective Use of Pesticides, Second Edition* (Oakland: University of California Division of Agriculture and Natural Resources; Berkeley: University of California Press, 2000), page 285.

Helpful Conversion Factors*

Pesticide Application Equipment and Calibration

for Non-Agricultural Applicators

Standard Measure	Metric Conversions
Volume 1 tsp = 0.17 fl oz 1 tbs = 3 tsp 1 fl oz = 2 tbs = 6 tsp 1 cup = 8 fl oz =16 tbs 1 pt = 2 cups = 16 fl oz 1 qt = 2 pt =32 fl oz 1 gal = 4 qt = 8 pt = 128 fl oz = 231 cu in	**Volume** 1 fl oz = 29.5 ml = 0.0295 L 1 pt = 473 ml = 0.473 L 1 qt = 946 ml = 0.946 L 1 gal = 3785 ml = 3.785 L 1 ml = 0.033 fl oz 1 L = 33.8 fl oz = 2.113 pt =1.057 qt = 0.264 gal
Weight 1 oz = 0.0625 lb 1 lb = 16 oz 1 ton = 2,000 lb 1 gal of water = 8.34 lb	**Weight** 1 oz = 28.35 g 1 lb = 454 g = 0.4536 kg 1 ton = 907 kg 1 gal of water = 3.786 kg 1 g = 0.035 oz 1 kg = 35.27 oz = 2.205 lb

* Reproduced from *The Safe and Effective Use of Pesticides, Second Edition* (Oakland: University of California Division of Agriculture and Natural Resources; Berkeley: University of California Press, 2000), page 285.

Information and Resources

Calibrating Liquid Application Equipment

Before you calibrate liquid sprayers

- Flush out the tank and pumping system
- Clean and replace filter screens
- Check and replace worn nozzles
- Lubricate bearings and appropriate moving parts
- Inspect hoses for leaks
- Make sure pressure gauge is working properly

128th Acre Broadcast Sprayer Calibration Method *(for backpack sprayers and other small sprayers with 5 gallon tanks or less)*

Adapted from **Carl E. Bell, Cheryl Wilen, and Milton McGiffen, Jr. University of California Cooperative Extension, Invasive Plants in Southern California,** **http://www.cal-ipc.org/symposia/archive/pdf/2014/Cal_IPC_calibration_chart_10082014.pdf**

If the label rate is ounces or pounds per acre:	
Step 1	Measure out the 128th acre area (340 sq ft) – such as 10 ft by 34 ft or 18.5 ft by 18.5 ft.
Step 2	Spray the area evenly and record the time. Time:______
Step 3	Spray water into a bucket for the same amount of time you recorded in Step 2. Measure it in ounces; this will equal the gallons per acre (GPA) that the sprayer is applying. Record this as Step 3 in the box on page 2 of this sheet.
Rate calculation:	
Step 4	Record the volume of your spray tank in gallons. Record this as Step 4.
Step 5	On the pesticide label, find the amount to be applied per acre in ounces. Record this as Step 5.
Step 6	Divide the volume of the spray tank (Step 4) by gallons per acre (Step 3) to get acres per tank load. Record this as Step 6.
Step 7	Multiply the label rate (Step 5) by acres per tank load (Step 6) to get how many ounces of pesticide per tank load.

Step 4 ______________ spray tank volume	÷	**Step 3** ______________ GPA	=	**Step 6** ______________ acres per tank load
Step 5 ______________ ounces of pesticide per acre	X	**Step 6** ______________ acres per tank load	=	**Step 7** ______________ pesticide per tank load in ounces

Calibrating larger sprayers (holding more than 5 gallons)

Determine the

- Tank capacity
- Travel speed
- Flow rate
- Swath width

Tank capacity

- Make sure sprayer is on level surface and tank is empty
- Close all valves
- Add measured amounts of water until tank is full and mark volume on the tank
- Record total volume of water and permanently paint or engrave fill level line onto the outside of the tank
- Return the tank to a level surface before you read the markings

Travel speed

- Measure travel speed under actual working conditions
- Use a 100-ft tape to measure distance
- Drive through the distance while maintaining desired speed
- Record time travelled with a stopwatch
- Repeat process
- Divide distance by time to get speed

Calculating travel speed	
Example: Three runs were made Run 1: 1 minute 48 seconds **1. Convert seconds to minutes** 48 sec X 1min/60 sec = 0.8 minutes Run 1: 1 minute 48 seconds = 1.8 minutes Run 2: 1 minute 40 seconds = 1.67 minutes Run 3: 1 minute 52 seconds = 1.87 minutes	**2. Add the three runs up and divide by 3.** 1.80 + 1.67 + 1.87 5.34 min ÷ 3 = 1.78 min **Distance = 300 ft** **3. Divide distance by time** 300 ft ÷ 1.78 min = 168.5 ft/min

Flow rate

- Measure the output of the sprayer when nozzles are new and remeasure to adjust for wear
- Collect liquid from each nozzle separately over a measured period of time using a calibrated container and stopwatch
- Make sure the output for any one nozzle does not exceed the manufacturer's rated output by more than 10%
- Recalibrate if you make changes
    - Nozzle size or replacement
    - Spray location
    - Boom height
    - Travel speed
    - Pressure

Information and Resources

Calibrating Liquid Application Equipment

Calculating the flow rate			
Nozzle	**Output (volume ÷ seconds) fl oz ÷ sec**	**Multiply by 0.4688 (60 sec/min X 1 gal/128 fl oz)**	**gpm**
1	12.5 ÷ 23.2 = 0.539	X 0.4688 =	0.253
2	12.0 ÷ 22.5 = 0.533	X 0.4688 =	0.250
3	15.5 ÷ 24.8 = 0.625	X 0.4688 =	0.293
4	14.5 ÷ 26.1 = 0.556	X 0.4688 =	0.261
5	19.0 ÷ 27.2 = 0.699	X 0.4688 =	0.328
6	13.0 ÷ 23.9 = 0.544	X 0.4688 =	0.255
			Total output = 1.64 gal/min

Comparing flow rate among nozzles			
Nozzle	**gpm**	**Divide by rated output**	**Subtract 1 and multiply by 100**
1	0.253	÷ 0.250 = 1.012	- 1 X 100 = 1.2%
2	0.250	÷ 0.250 = 1.000	- 1 X 100 = 0%
3	0.293	÷ 0.250 = 1.172	- 1 X 100 = $\boxed{17.2\%**}$
4	0.261	÷ 0.250 = 1.044	- 1 X 100 = 4.4%
5	0.328	÷ 0.250 = 1.312	- 1 X 100 = $\boxed{31.2\%**}$
6	0.255	÷ 0.250 = 1.020	- 1 X 100 = 2.0%
These nozzles exceed the manufacturer's specs by more than 10% and need to be replaced.			

Information and Resources

Calibrating Liquid Application Equipment

Measuring swath width

- Multi-nozzle boom sprayer
  - Width of boom plus distance between one pair of nozzles or multiply number of nozzles by nozzle spacing
  - Make sure boom is level
  - Adjust height so that there is 30% overlap of spray (unless otherwise recommended by the manufacturer)
- Backpack sprayer
  - Swath width is based on the spray pattern left on the ground after a test run
  - Keep nozzle at the height used in an actual application

Determining the amount of pesticide to use

1. Multiply the travel speed by the swath width to determine the area covered in 1 minute.

Example:
Swath = 2.5 ft
Speed = 128.25 ft/min 128.25 ft/min X 2.5 ft = 320.63 sq ft/min

2. Divide the flow rate by the area covered in 1 minute to get the volume of spray for 1 sq ft.

Flow rate = 0.05 gal/min

0.05 gal/min ÷ 320.63 sq ft/min = 0.000156 gal/sq ft

3. Find out how many sq ft can be sprayed with 1 tank by dividing tank size (3 gal) by spray volume.

3 gal tank ÷ 0.000156 gal/sq ft = 19,231 sq ft/tank

4. Determine the amount of pesticide to use by multiplying the rate by sq ft sprayed with 1 tank. The label will give the rate.

Rate = 3 oz/1000 sq ft

3 oz/1000 sq ft X 19,231 sq ft/tank = 57.69 fl oz/tank

What to know when calibrating granule applicators

- Make sure equipment is clean and working properly before calibration
- Use the actual pesticide
- Wear personal protective equipment
- Calibrate at the treatment or similar site
- Measure out a test area
- Read the pesticide label for application rate
- Set spreader to appropriate setting
- Recalibrate for each type of granular pesticide applied

Factors to measure

- Travel speed
- Swath width
- Output rate

Travel speed

- Drop spreaders and rotary spreaders
    - Walk at a consistent pace
    - 3 miles per hour is standard
- Equipment on back of tractor
    - Fill hopper with granules
    - Measure off a distance and mark beginning and end with a marker
    - Drive through the distance while maintaining desired speed (don't apply granules)
    - Record time travelled with a stopwatch
    - Repeat process
    - Divide distance by time to get speed

Calculating travel speed

Example: Three runs were made	2. Add the three runs up and divide by 3.
Run 1: 1 minute 30 seconds	1.50 + 1.42 + 1.75 4.67 min ÷ 3 = 1.56 min
1. Convert seconds to minutes	**Distance = 300 ft**
30 sec X 1min/60 sec = 0.5 minutes	**3. Divide distance by time**
Run 1: 1 minute 30 seconds = 1.5 minutes Run 2: 1 minute 25 seconds = 1.42 minutes Run 3: 1 minute 45 seconds = 1.75 minutes	300 ft ÷ 1.56 min = 192.3 ft/min

Measuring swath width and determining output rate

- Operate equipment under actual field conditions
- Output rate = weight of granules divided by area

1. Determine swath width
   - If the swath width is larger than the tarp width, use tarp area in calculations
   - If the swath width is less than the tarp width, find the area by multiplying the swath width by the tarp length
2. Find weight of granules (larger spreaders)
   - Operate spreader at a known speed over a tarp
   - Collect granules and weigh them
3. Find weight of granules (smaller spreaders)
   - Fill the hopper with a known weight of granules
   - Operate equipment over a known area
   - After a time, weigh the granules remaining
   - The difference in weight is the amount of granules applied

Calculating output rate	
Example: Tarp size = 10 ft by 12 ft Weight of granules = 8 oz **1. Calculate area** Area = 10 X 12 = 120 sq ft	**2. Convert granule weight in ounces to pounds** 8 oz X 1lb/16 oz = 0.5 lb **3. Calculate output rate** Output rate = weight of granules ÷ area 0.5 lb ÷ 120 sq ft = 0.004 lbs / sq ft

Determining the amount of pesticide to use for a hand-pushed broadcast spreader
1. Determine the area treated per minute (swath width X travel speed) Example: Swath = 10 ft   Output rate = 2.5 lbs/min Speed = 200 ft/min   Total area = 1200 sq ft 10 ft X 200 ft/min = 2000 sq ft/min
2. Determine pounds of pesticide applied per sq ft (output rate ÷ area treated per minute) 2.5 lbs/min ÷ 2000 sq ft/min = 0.00125 lbs/sq ft
3. Find out how many pounds of granules are needed for 1200 sq ft (total area X pesticide applied per sq ft) 1200 sq ft X 0.00125 lbs/sq ft = 1.5 lbs

Active ingredient calculations

- Allow you to apply the same amount of active ingredient to a unit of area, regardless of the product or formulation used
- Only apply the formulated amount according to the label

Calculating active ingredient (a.i.) for liquid sprayers

Example:

- 3 gallon backpack sprayer
- Sprays 0.5 acre per tank
- Recommendation: Spray 1.5 pounds of a.i. per acre
- Liquid pesticide contains 4 lbs. a.i. per gallon

How many gallons of pesticide do you add to the tank?

1. Determine the number of acres that can be treated with 1 gallon of pesticide.

4 lbs a.i./gal ÷ 1.5 lbs a.i./acre = 2.67 acres/gallon

2. Divide tank capacity by acres of pesticide covered per gallon.

0.5 acres/tank ÷ 2.67 acres/gallon = 0.19 gallons per tank

3. Convert to ounces.

0.19 gallons X 128 fl oz/gallon = 24 oz

You must use 24 oz of product in the tank along with enough water to bring it up to 3 gallons for spraying 0.5 acres

Calculating active ingredient (a.i.) for dry formulations

Example:

- Wettable powder formulation contains 75% a.i.
- Sprayer covers 0.5 acre per tank
- Recommendation: Spray 1.5 pounds of a.i. per acre

How many pounds of pesticide do you add to the tank?

1. **Convert the percentage of a.i. to a decimal.**

   75% ÷ 100 = 0.75 lb of a.i./lb of product

2. **Divide the amount of a.i. you want to use by the amount in the formulated product.**

   1.5 lb a.i./acre ÷ 0.75 lb ai/lb product = 2 lbs product/acre

3. **Figure out how much to add per tank when your tank covers 0.5 acres per tank.**

   0.5 acres/tank X 2 lbs product/acre = 1 lb product/tank

Percentage and Parts Per Million Solutions

- Rates often used with plant growth regulators
- Final percentage for sprays listed on the label refers to the amount of formulated pesticide.
- Percentage solutions are mixed on a weight/weight basis (pounds of active ingredient (a.i.) per pound of water)
- Read pesticide label and understand the instructions

Calculating percentage solutions for liquid formulations

Example:

- Prepare a 1% solution
- Formulated pesticide contains 5.4 lbs a.i. per gallon
- Tank holds 14.5 gallons of water

How many pounds of pesticide do you add to the tank?

1. **Find the weight of the liquid in the filled tank. (Water = 8.34 lbs/gal)**

   14.5 gal X 8.34 lbs/gal = 120.93 lbs

2. **Multiply the weight of water in the tank by 1% (0.01) to determine the amount of pesticide a.i. you'll need to add.**

   120.93 lbs X 0.01 = 1.21 lbs a.i. needed

3. **Divide the weight of the a.i. needed by the weight of the a.i. in the product.**

   1.21 lbs a.i. ÷ 5.4 a.i./gal = 0.22 gal

For a 14.5 gallon tank, 0.22 gallons should be the pesticide product and 14.28 gallons should be water so that the combined amount is 14.5 gallons (14.5 gallon tank = 0.22 gal pesticide product + 14.28 gal water)

Calculating ppm solutions for liquid formulations

Example:

- Prepare 100 ppm concentration
- Tank holds 25 gallons of water
- Formulated pesticide product contains 5.4 lbs active ingredient (a.i.) per gallon

How much pesticide do you add to the tank?

1. Find the weight of the liquid in the filled tank. (Water = 8.34 lbs/gal)

25 gal X 8.34 lbs/gal = 208.5 lbs

2. Multiply the weight of water in the tank by 0.0001 lbs to determine the amount of pesticide a.i. you'll need to add. (100 ppm = 100/1,000,000 or 0.0001 pounds)

208.5 lbs X 0.0001 = 0.021 lbs a.i. needed

3. Divide the weight of the a.i. needed by the weight of the a.i. in the product.

0.021 lbs a.i. ÷ 5.4 a.i./gal = 0.00389 gal

3. Convert to ounces.

0.00389 gal X 128 fl oz/gal = 0.50 fl oz

Information and Resources

Calibrating Soil Drenching and Soil Injection Equipment

What is soil drenching and injection?

- Application of systemic pesticides to trees, hedges, shrubs, or clumped groups of plants
- Pesticides are absorbed by plant roots and move to growing points in trees and bushes

Tree injection and implants

- Capsules with a pre-measured amount of pesticide
    - Number of capsules to use depends on diameter at breast height (DBH)
    - Slow-release capsules remain in holes that you drill in the tree trunk
- Tree injection
    - Drill holes
    - Inject measured amount of pesticide with high-pressure gun

Soil drenching: Calculating application rate using DBH for individual trees or shrubs

Read the label to find the rate of application (usually stated by the amount needed per inch of plant height or per inch of trunk DBH)

1. **Wrap a tape measure or string around the trunk at chest height.**

   Diameter = circumference X 0.32

2. **Calculate the application rate.**

   Example:
   Label rate = 1.2 tsp per inch of trunk diameter
   Tree DBH = 15-inch
   Application rate = DBH X labeled rate

   15 inches X 1.2 tsp/inch = 18 tsp

3. **Convert to liquid ounces.**

   18 tsp ÷ 6 tsp/oz = 3 oz

4. **For more than one tree, multiply the application rate by the number of trees you have.**

5. **Determine how much water to mix by reading the label. Mix the pesticide in a bucket containing the measured amount of water.**

Soil drenching: Calculating application rate for grouped plantings of trees or shrubs

1. **Determine the height of each tree or shrub, and add all the heights together.**
2. **Determine the amount of pesticide to apply by dividing the cumulative height by the label rate.**

Example:
Site = Bed of 6 shrubs
Label rate = 1 ounce/20 cumulative feet
Height = 30 cumulative feet

30 ft ÷ 20 ft/oz = 1.5 oz

3. **Determine how much to dilute it before application.**

Example:
Label = dilute in 10 gallons water/1000 sq ft treated surface
Site = 4 ft by 25 ft soil bed = 100 sq ft

10 gal/1000 sq ft = 0.01 gallons/sq ft
100 sq ft X 0.01 gallon/sq ft = 1 gallon of water needed for the treatment area

Dilute 1.5 fl oz pesticide in a minimum of 1 gallon of water

Information and Resources

Calibrating Soil Drenching and Soil Injection Equipment

Calibrating powered soil injection equipment

1. Fill tank with water
2. Place the end of the injection probe into a calibrated container
3. Turn on the equipment
4. Measure the output delivered in 1 minute
5. Repeat several times to get an average

Example:
Apply 128 fl oz (4 quarts) of diluted pesticide to the soil
Use 4 injection sites – 1 qt in each hole
Output = 5 qts/min

How long will it take to deliver 1 qt?
1 qt ÷ 5 qts/min = 0.20 minutes   0.20 min X 60 sec/min = 12 seconds

It will take 12 seconds to inject 1 qt of mixture into 1 hole

Calibrating hand held injectors

1. **Measure the output.**

   Example: Label tells you to set injector to the 5 ml setting to deliver 1/6 fl oz per stroke (to apply 1 fl oz, you need 6 strikes)

2. **Set the injector and fill with water.**
3. **Place a firm object in the bottom of a container, rest the probe on the object and make 12 strikes.**
4. **Measure the water captured in the container.**
5. **Repeat the process to get an average.**

Example:
At the 5 ml setting, 12 strikes release 2 fl oz
Label rate = inject 20 fl oz around each tree   You use 5 soil injection holes

20 fl oz ÷ 5 holes = 4 fl oz/hole

If 12 strikes release 2 oz, then you need to make 24 strikes into each hole to release 4 fl oz