PESTICIDE RATE AND DOSAGE CALCULATIONS

Milton D. Taylor, Associate Coordinator, PSEP

HOW TO CALCULATE PESTICIDE DILUTIONS AND DOSAGES FOR LARGE AREAS

Pesticides for use in sprays are generally available as wettable or soluble powders and as liquid concentrates. These must be diluted, usually with water, before use. Other diluents, such as deodorized kerosene, may be used for special applications.

The precise amount of water applied to an acre (or other given area) is of modest concern as long as gallonage falls within a recommended range, delivers the recommended amount of pesticide, provides adequate coverage, and does not result in excessive runoff or drift. If you know the area (acres, sq ft, etc.) or units (trees, cows, etc.) covered by a given amount of spray you can determine the dosage or rate of active ingredient each receives by adding the proper quantity of pesticide to that amount of water. Dusts and granules are applied without dilution by the user. Therefore, the amount applied per acre or other unit is much more critical because you have no other way of controlling the dosage or rate of active ingredient.

The amount of active ingredient in liquid concentrates is expressed in pounds per gallon. In granules, dusts, wettable or soluble powders, and other solids it is nearly always expressed as percent by weight. Application rates are usually expressed as amount of pesticide product but sometimes they may be expressed as pounds of active ingredient or actual toxicant. Actual toxicant and active ingredient are practically synonymous.

1. To find the pounds of wettable powder (WP), dust (D) or granules (G) per acre to obtain the desired pounds of active ingredient (ai) per acre:

$$\textit{lbs of WP, D, or G per acre} = \frac{\textit{lbs ai desired x 100}}{\textit{\% ai in WP, D, or G}}$$

2. To find the pints of liquid concentrate per acre to obtain the desired pounds of active ingredient (ai) per acre:

   * *If you want the answer in gallons, quarts, or fluid ounces substitute l, 4, or l28 respectively for 8.*

$$\textit{conc. per acre} = \frac{\textit{lbs. ai desired x 8*}}{\textit{lbs ai per gallon of liq. conc.}}$$

3. To find the amount of wettable powder (WP) or liquid concentrate to use in a given amount of spray:

   amt. of WP or liq. conc. = no. of acres treated with amount of spray X desired amount of WP or liq. conc. per acre*

   **Trees, animals, etc. can be substituted for acres.*

4. To find the pounds of wettable powder needed to obtain a desired percentage of active ingredient in water:

$$\textit{lbs of WP} = \frac{\textit{gals of spray desired x \% ai desired x 8.3**}}{\textit{\% ai in WP}}$$

5. To find the gallons of liquid concentrate needed to obtain a desired percentage of active ingredient in water:

   ** *One gallon of water weighs approximately 8.3 pounds. If another diluent is used the weight per gallon of the other diluent should be substituted for 8.3.*

$$\textit{gal of liq. conc.} = \frac{\textit{gals of spray desired x \% ai desired x 8.3**}}{\textit{lbs ai per gal of liq. conc. x 100}}$$

PESTICIDE RATE AND DOSAGE CALCULATIONS

PESTICIDE CONVERSION TABLE FOR LARGE AREAS

LIQUID FORMULATIONS

Amount of Commercial Product to Add to Spray Tank for Each Acre Treated

FORMULATION LBS/GAL ACTIVE INGREDIENT	Desired Rate Per Acre of Active Ingredient, Lbs															
	0.1	0.2	0.3	0.4	0.5	0.6	0.8	1	1.1	1.5	2	2.5	3	4	6	9
1.5	10 oz	17 oz	26 oz	34 oz	43 oz	51 oz	64 oz	85 oz	96 oz	128 oz	171 oz	213 oz	256 oz	341 oz	512 oz	768 oz
2	8 oz	13 oz	19 oz	26 oz	32 oz	38 oz	48 oz	64 oz	72 oz	96 oz	128 oz	160 oz	192 oz	256 oz	384 oz	576 oz
3	5 oz	9 oz	13 oz	17 oz	21 oz	26 oz	32 oz	43 oz	48 oz	64 oz	85 oz	107 oz	128 oz	171 oz	256 oz	384 oz
4	4 oz	6 oz	10 oz	13 oz	16 oz	19 oz	24 oz	32 oz	36 oz	48 oz	64 oz	80 oz	96 oz	128 oz	192 oz	288 oz
6	2.6 oz	4.3 oz	6.4 oz	9 oz	11 oz	13 oz	16 oz	21 oz	24 oz	32 oz	43 oz	53 oz	64 oz	85 oz	128 oz	192 oz
6.7	2.3 oz	3.8 oz	5.7 oz	7.6 oz	9.6 oz	11.5 oz	14.3 oz	19.1 oz	21 oz	29 oz	38 oz	48 oz	57 oz	76 oz	115 oz	172 oz
7	2.2 oz	3.7 oz	5.5 oz	7.3 oz	9.1 oz	11 oz	13.7 oz	18 oz	20 oz	27 oz	37 oz	46 oz	55 oz	73 oz	110 oz	165 oz
8	2 oz	3.2 oz	4.8 oz	6.4 oz	8 oz	9.6 oz	12 oz	16 oz	18 oz	24 oz	32 oz	40 oz	48 oz	64 oz	96 oz	144 oz

WETTABLE POWDER FORMULATIONS

Pounds of Commercial Product to Add to Spray Tank for Each Acre Treated

% ACTIVE INGREDIENT	Desired Rate Per Acre of Active Ingredient, Lbs																
	0.2	0.3	0.4	0.5	0.6	0.8	0.8	1	2	2	3	3	4	4	5	8	10
50	0.4	0.6	0.8	1	1.2	1.5	1.6	2	2	3	4	5	6	8	10	16	20
75	0.3	0.4	0.5	0.7	0.8	1	1.1	1.3	2	2	3	3	4	5.3	6.6	10.7	13.33
80	0.3	0.4	0.5	0.6	0.8	0.9	1	1.2	2	2	3	3	4	5	6.2	10	12.5

PESTICIDE CONVERSION TABLE FOR LARGE AREAS (*continued*)

GRANULES AND DUSTS

Pounds of Commercial Product to Apply Per Acre

% ACTIVE INGREDIENT	Desired Rate Per Acre of Active Ingredient, Lbs					
	1	2	3	4	5	10
2.5	40	80	120	160	200	400
5	20	40	60	80	100	200
10	10	20	30	40	50	100
15	6.6	13.3	20	26.6	33.3	66.6
20	5	10	15	20	25	50

CONVERSION TABLES FOR SMALL AREAS

LIQUID FORMULATIONS[1]

Amount of Commercial Product to Add to Spray Tank to Treat l000 Sq Ft

FORMULATION LBS/GAL ACTIVE INGREDIENT	Desired Rate Per Acre of Active Ingredient, Lbs							
	0.25	0.5	1	2	4	8	10	12
0.5	3 Tbsp[1] (43.4)[3]	3 oz[2] (86.8)	6 oz (173.7)	11 oz 1 Tbsp (347.4)				
1	1 Tbsp 1 tsp (21.7)	3 Tbsp (43.4)	3 oz (86.8)	5 oz 1 Tbsp (173.7)				
2	2 tsp (10.8)	1 Tbsp 1 tsp (21.7)	3 Tbsp (43.4)	3 oz (86.8)	5 oz 1 Tbsp (173.7)	11 oz 1 Tbsp (342.4)		
4	1 tsp (5.4)	2 tsp (10.8)	1 Tbsp 1 tsp (21.7)	3 Tbsp (43.4)	3 oz (86.8)	6 oz (173.7)	7 oz 2 tsp (217.1)	8 oz 4 tsp (260.6)

[1] approximate values
[2] refers to level measure
[3] figure in parentheses refers to milliliters

PESTICIDE RATE AND DOSAGE CALCULATIONS

CONVERTING LARGE VOLUME RECOMMENDATIONS TO SMALL VOLUMES OR AREAS

Frequently, pesticide recommendations are given only for large volume applications, i.e. amount per l00 gallons or per acre, but only a small amount is needed. Conversion of liquids to smaller quantities is relatively easy and precise because suitable equipment such as measuring spoons are readily available. While scales sensitive enough to handle small quantities of solid materials are available, it is often more practical to use volumetric measures. Various conversion tables have been prepared on the premise that there are 200 to 300 teaspoons (roughly 2-3 pints) per pound of solid pesticide product. These tables are grossly inaccurate because of the wide variation in bulk density among solid pesticide formulations. For instance, a pint of almost any insecticide wettable powder will weigh much less than a pint of fungicide that has a high metal content. Greater accuracy can be obtained if one first determines the weight of a given volume of the solid material and then calculates the volumetric measure. This will usually provide acceptable accuracy but it is still not as accurate as actually weighing a solid formulation. When coupled with a little simple arithmetic the following formulas will enable you to convert large volume recommendations to smaller quantities:

1. To find the amount of liquid concentrate per gallon when label recommendations are given in pints per 100 gallons:

teaspoons/gallon = recommended pints per 100 gallons x 1*

or

teaspoons/gallon = recommended pints per l00 gallons x 0.96

or

milliliters/gallon = recommended pints per 100 gallons x 4.73*

2. To find the amount of wettable powder (WP) or other solid formulation per gallon when label recommendations are given as pounds per 100 gallons:

teaspoons/gallon = recommended lbs/100 gals x cups in 1 lb of formulation x 0.053*

or

teaspoons/gallon = recommended lbs/100 gals x Tbsps in 1 oz of formulation x 0.53*

or

grams/gallon = recommended lbs/100 gals x 4.54*

3. To find the amount of liquid concentrate to apply per 1000 square feet when label recommendations are given as pints per acre:

teaspoons/1000 sq ft = recommended pints/acre x 2.20*

or

milliliters/1000 sq ft = recommended pints/acre x 10.9*

4. To find the amount of dust (D), granules (G) or wettable powder (WP) to apply per 1,000 square feet when label recommendations are given as pounds per acre:

lbs./1000 sq ft = recommended lbs/acre x 0.023*

or

Tbsps/1000 sq ft = recommended lbs/acre x cups in 1 lb of formulation x 0.37*

or

Tbsps/1000 sq ft = recommended lbs/acre x Tbsps in 1 lb of formulation x 0.023*

or

grams/1000 sq ft = recommended lbs/acre x 10.4*

*These values have been rounded off to facilitate calculations.

CALIBRATION METHOD FOR HYDRAULIC BOOM AND BAND SPRAYERS, AND OTHER LIQUID APPLICATORS

Gary L. Hawkins, Extension Engineer
Glen C. Rains, Extension Engineer

The procedure below is based on spraying 1/128 of an acre per nozzle or row spacing and collecting the spray that would be released during the time it takes to spray the area. Because there are 128 ounces of liquid in 1 gallon, this convenient relationship results in ounces of liquid caught being directly equal to the application rate in gallons per acre.

Calibrate with clean water when applying toxic pesticides mixed with large volumes of water. Check uniformity of nozzle output across the boom. Collect from each for a known time period. Each nozzle should be within 10 percent of the average output. Replace with new nozzles if necessary. When applying materials that are appreciably different from water in weight or flow characteristics, such as fertilizer solutions, etc., calibrate with the material to be applied.

Exercise extreme care and use protective equipment when active ingredient is involved.

Step 1. Determine type of application to be made and select appropriate procedure from Table 1. For example, for a Herbicide Broadcast, use Procedure A.

Note: Determine and use average row spacing for modified row patterns. In skip row patterns, use width of area covered per row as row spacing.

Step 2. Using procedure A, B, or C below as selected in Step 1, determine appropriate calibration distance from Table 2.

(A) Broadcast Application: Outlets or nozzles must be evenly spaced. Measure outlet (nozzle, etc.) spacing. Find this spacing in left column of Table 2 and read the corresponding calibration distance. For example, for a 19-inch spacing the distance would be 214.9 feet.

(B) Band Application: Measure band width. Find this band width in the left column of Table 2 and read the corresponding calibration distance. For example, for a 12-inch band, the distance would be 340.3 feet.

(C) Row Application: Measure row spacing for evenly spaced rows. Find this row spacing in the left column of Table 2 and read the corresponding calibration distance from the column on the right. For example, for a 38-inch row spacing, the distance would be 107.5 feet. (See note above for modified and skip rows.)

Step 3. Measure and mark calibration distance in a typical portion of the field to be sprayed.

Step 4. With all attachments in operation (harrows, planters, etc.) and traveling at the desired operating speed, determine the number of seconds it takes to travel calibration distance. Be sure machinery is traveling at full operating speed the full length of the calibration distance. Mark or make note of engine RPM and gear. Machine must be operated at same speed for calibration.

Table 1. Corresponding procedures for different spray applications.

TYPE OF APPLICATION	PROCEDURE	COVERAGE BASIS
	Herbicide, Insecticide, Nematicide, Fungicide, or Liquid Fertilizer	
Broadcast	A	Broadcast (gal/acre)
Band	B	Broadcast (gal/acre of band)
Row (See note)	C (Use this procedure when rates are given for row treatment)	

CAUTION: AGRICULTURAL CHEMICALS CAN BE DANGEROUS. IMPROPER SELECTION OR USE CAN SERIOUSLY INJURE PERSONS, ANIMALS, PLANTS, SOIL, OR OTHER PROPERTY. BE SAFE. SELECT THE RIGHT CHEMICAL FOR THE JOB. HANDLE IT WITH CARE. FOLLOW THE INSTRUCTIONS ON THE CONTAINER LABEL AND INSTRUCTIONS FROM THE EQUIPMENT MANUFACTURER.

Step 5. With sprayer sitting still and operating at same throttle setting or engine RPM as used in Step 4, adjust pressure to the desired setting. Machine must be operated at same pressure used for calibration.

Step 6. For Procedure A, Step 2, broadcast application, collect spray from one nozzle or outlet for the number of seconds required to travel the calibration distance.

For Procedure B, Step 2, band application, collect spray from all nozzles or outlets used on one band width for the number of seconds required to travel the calibration distance.

For Procedure C, Step 2, row application, collect spray from all outlets (nozzles, etc.) used for one row for the number of seconds required to travel the calibration distance.

Step 7. Measure the amount of liquid collected in fluid ounces. The number of ounces collected is the gallons per acre rate on the coverage basis indicated in Table 1. For example, if you collect 18 ounces, the sprayer will apply 18 gallons per acre. Adjust applicator speed, pressure, nozzle size, etc. to obtain recommended rate. If speed is adjusted, start at Step 4 and recalibrate. If pressure or nozzles are changed, start at Step 5 and recalibrate.

Step 8. To determine amount of pesticide to put into a sprayer or applicator tank, divide the total number of gallons of mixture to be made (tank capacity for a full tank) by the gallons per acre rate from Step 7 and use recommended amount of pesticide for this number of acres.

Band Application

Use the recommended broadcast pesticide rates to make tank mixtures for band applications when calibrating with procedure (B) of this method. The number of gallons per acre determined in Step 7 are the gallons that will be applied to each acre of actually treated band.

To determine the gallons of spray mixture required to make a band application on a field, the number of acres that will be in the actually treated band must be determined. When all treated bands are the same width and all untreated bands are the same width (which is usually the case) the acres in the actually treated band can be calculated by placing the width of the treated band over the sum of the widths of the treated band and the untreated band. Then, multiplying this fraction times the number of acres in the field. Example: How many acres will actually be treated in a 30 acre field if a 12” band of chemical is applied over the drill of rows spaced 36” apart. The treated band width is 12”. The untreated band width is (36”- 12”) = 24”. Acres actually treated will be 12” divided by (12” + 24”)

Table 2. Calibration distances with corresponding widths.

ROW SPACING, OUTLET SPACING OR BAND WIDTH (Whichever Applies) (Inches)	CALIBRATION DISTANCE (feet)
48**	85.1
46	88.8
44	92.8
42	97.2
40	102.1
38	107.5
36	113.4
32	127.6
30	136.1
24	170.2
20	204.2
19	214.9
18	226.9
14	291.7
12	340.3
10	408.4
8	510.5

To determine distance for spacing or band width not listed, divide the spacing or band width expressed in feet into 340.3. Example: For a 13” band the calibration distance would be 340 divided by 13/12 = 314.1.

** To increase calibration accuracy for a wide nozzle spacing, multiply calibration distance by a factor (for example, 2); then, divide the fluid amount collected by the same factor for GPA. For narrow nozzle spacings with long calibration distances, divide calibration distance by a factor (for example, 4); then, multiply the fluid amount collected by the same factor for GPA.

times 30 acres equals 10 acres. The amount of mixture required will be 10 times the number of gallons per acre from Step 7. The amount of chemical required will be 10 times the recommended broadcast rate for one acre.

Check rate recommendations carefully as to type of application, broadcast, band or row, and type of material specified, formulated product, active ingredient, etc.

Calculating Formulation Requirements for Active Ingredient Rates.

To determine amount of liquid pesticide required for a rate given in pounds of active ingredient per acre, divide recommended rate by pounds active ingredient per gallon stated on label. Example: Pesticide label states 4 lb active ingredient (AI) per gallon and recommends 1/2 lb ai per acre. Amount of pesticide required: 1/2 lb ai per acre divided by 4 lb ai per gal = 1/8 gal per acre.

To determine amount of wettable powder required for a rate given in pounds active ingredient per acre, divide recommended rate by percent active ingredient stated on label. Example: Pesticide label states powder is 50% active ingredient. Two pounds of active ingredient is recommended per acre. Amount of pesticide powder required: 2 lb ai per acre divided by 0.5 ai per lb = 4 lb per acre.

CALIBRATION METHOD FOR BOOMLESS BROADCAST SPRAYERS

Gary L. Hawkins, Extension Engineer
Glen C. Rains, Extension Engineer

All sprayers should be calibrated often to ensure that pesticide is being applied at the correct rate. Most broadcast applications are made with a boom arrangement where the nozzle tips are spaced evenly along the boom. However, in some situations this may be impossible or undesirable, so a cluster nozzle or a single nozzle with a wide spray pattern may be used.

Calibrate with clean water when applying toxic pesticides mixed with large volumes of water. When applying materials that are appreciably different from water in weight or flow characteristics, such as fertilizer solutions, calibrate with the material to be applied. Exercise extreme care and use protective equipment when active ingredient is involved.

The following instructions outline a simple method to calibrate a boomless broadcast sprayer.

Step 1. Determine spray width. The spray width is the distance between successive passes through a field. This is usually given in the manufacturers' literature for a specific nozzle. If you are unable to find this in the catalogs, use 80-85% of the wetted spray width.

Step 2. Using the spray width in Step 1, determine the calibration distance from Table 1.

Step 3. Measure and mark calibration distance on typical terrain to be sprayed.

Step 4. With all attachments in operation and traveling at the desired operating speed, determine the number of seconds it takes to travel the calibration distance. Be sure machinery is traveling at full operating speed the full length of the calibration distance. Mark or make note of engine RPM and gear. Machine must be operated at same speed for calibration.

Step 5. With sprayer sitting still and operating at same throttle setting or engine RPM as used in Step 4, adjust pressure to the desired setting. Machine must be operated at same pressure used for calibration.

Step 6. Collect spray from all nozzles or outlets for the number of seconds required to travel the calibration distance.

Table 1. Calibration distances with corresponding widths.

SWATH WIDTH (feet)	CALIBRATION DISTANCE (feet)
40	85.1
38	89.5
36	94.5
32	106.3
30	113.4
28	121.5
24	141.8
20	170.2
18	189
16	212.7
12	283.6
10	340.3
8	425

To determine distance for swath width not listed, divide the swath width expressed in feet into 340.3 and multiply by 10. Example: For 13 feet swath the calibration distance would be 340.3 divided by 13 multiplied by 10 = 261.8.

Step 7. Measure the amount of liquid collected in fluid ounces.

Step 8. Divide the total number of fluid ounces by 10 to obtain gallons per acre applied. For example, if you collect 180 ounces, the sprayer will apply 18 gallons per acre. Adjust applicator speed, pressure, nozzle size, etc. to obtain recommended rate. If speed is adjusted, start at Step 3 and recalibrate. If pressure or nozzles are changed, start at Step 5 and recalibrate.

Step 9. To determine amount of pesticide to put into a sprayer or applicator tank, divide the total number of gallons of mixture to be made (tank capacity for a full tank) by the gallons per acre rate from Step 8 and use recommended amount of pesticide for this number of acres.

CAUTION: AGRICULTURAL CHEMICALS CAN BE DANGEROUS. IMPROPER SELECTION OR USE CAN SERIOUSLY INJURE PERSONS, ANIMALS, PLANTS, SOIL, OR OTHER PROPERTY. BE SAFE. SELECT THE RIGHT CHEMICAL FOR THE JOB. HANDLE IT WITH CARE. FOLLOW THE INSTRUCTIONS ON THE CONTAINER LABEL AND INSTRUCTIONS FROM THE EQUIPMENT MANUFACTURER.

CALIBRATION METHOD FOR GRANULAR APPLICATIONS

Gary L. Hawkins, Extension Engineer
Glen C. Rains, Extension Engineer

Applicators used in granular applications should be calibrated to ensure uniformity and accuracy of the application. A more accurate and uniform application can reduce the quantity of an active ingredient required for a given degree of control, which benefits the environment as well as the producer.

Several factors influence the amount of granular material applied to a given area. Granular material is usually metered with an adjustable orifice. The amount of material that flows through the orifice per revolution relies on orifice opening size and may rely on rotor speed. A wide variation in product characteristics, such as size, density, and shape, requires that a calibration be made for every chemical applied. Also changes in climatic conditions, such as temperature and humidity, can result in a different flow rate.

CAUTION: Calibration is done using the chemical to be applied. Protective equipment, such as rubber gloves, should be used to avoid contact with the chemicals to be applied.

Granular application is usually done in combination with another operation, such as planting or cultivating. The applicator may be ground driven or driven with a small electric motor. The following procedure will give the pounds (total weight) of material applied per acre broadcast or row basis as indicated. A weight scale incremented in ounces is required for this procedure.

Step 1. Determine type of application to be made and select appropriate procedure from Table 1. Example: Broadcast - Procedure A.

Step 2. Using procedure A, B, or C below as selected in Step 1, determine appropriate calibration distance from Table 2.

(A) Broadcast Application: Outlets must be evenly spaced. Measure outlet spacing. Find this spacing in left column of Table 2 and read the corresponding calibration distance. Example: for a 19” spacing the distance would be 214.9 feet.

(B) Band Application: Measure band width. Find this band width in the left column of Table 2 and read the corresponding calibration distance. Example: for a 12” band, the distance would be 340.3 feet.

(C) Row Application: Measure row spacing for evenly spaced rows. Find this row spacing in the left column of Table 2 and read the corresponding calibration distance from the column on the right. Example: for a 38” row spacing, the distance would be 107.5 feet.

Step 3. Measure and mark calibration distance in a typical portion of the field to be applied.

Step 4. With all attachments in operation (harrows, planters, etc.) and traveling at the desired operating speed, determine the number of seconds it takes to travel calibration distance. Be sure machinery is traveling at full operating speed the full length of the calibration distance. Mark or make note of engine RPM and gear. Machine must be operated at same speed for calibration.

Table 1. Corresponding procedures for different spray applications.

TYPE OF APPLICATION	PROCEDURE	COVERAGE BASIS (VOLUME OF APPLICATION)
Broadcast	A	Broadcast (lbs/acre)
Band	B	Broadcast (lbs/acre of band)
Row (See note)	C (Use this procedure when rates are given for row treatment)	

Note: Determine and use average row spacing for modified row patterns. Use width of area covered per row as row spacing in skip row patterns for broadcast rates

CAUTION: AGRICULTURAL CHEMICALS CAN BE DANGEROUS. IMPROPER SELECTION OR USE CAN SERIOUSLY INJURE PERSONS, ANIMALS, PLANTS, SOIL, OR OTHER PROPERTY. BE SAFE. SELECT THE RIGHT CHEMICAL FOR THE JOB. HANDLE IT WITH CARE. FOLLOW THE INSTRUCTIONS ON THE CONTAINER LABEL AND INSTRUCTIONS FROM THE EQUIPMENT MANUFACTURER.

Step 5. Multiply the number of seconds required to travel calibration distance by 8. This is the number of seconds to collect.

Step 6. With applicator sitting still and operating at same speed as used in Step 4, adjust gate openings to desired setting. Check uniformity of outlets across the swath or rows. Collect from each outlet for a known time period. Each outlet should be within 5 percent of the average outlet output.

Step 7. **For procedure (A), Step 2, broadcast application, collect from **one** outlet for the number of seconds indicated in Step 5.

For procedure (B), Step 2, band application, collect from **all** outlets used on one band width for the number of seconds indicated in Step 5. For procedure (C), Step 2, row application, collect from all outlets used for one row for the number of seconds indicated in Step 5.

** For ground driven equipment, multiply the calibration distance by 8 and collect from each outlet while traveling the calibration distance; then divide step 8 material collected by 8 for pounds per acre.

Step 8. Weigh the amount of material collected in ounces. The number of ounces collected is the pounds per acre rate on the coverage basis indicated in Table 1. For example, if you collect 18 ounces using procedure (A) or (B), the applicator will apply 18 pounds per acre on a broadcast coverage basis. Adjust applicator speed, gate opening, etc. to obtain recommended rate.

Step 9. Applicators should be checked for proper calibration every 4-8 hours of use. Simply repeat steps 7 and 8. If there is a difference of more than 5 percent of original calibration, check the system.

Table 2. Calibration distances with corresponding widths.

ROW SPACING, OUTLET SPACING OR BAND WIDTH (Whichever Applies) (Inches)	CALIBRATION DISTANCE (feet)
48*	85.1
46	88.8
44	92.8
42	97.2
40	102.1
38	107.5
36	113.4
32	127.6
30	136.1
24	170.2
20	204.2
19	214.9
18	226.9
14	391.7
12	340.3
10	408.4
8	510.5

To determine distance for spacing or band width not listed, divide the spacing or band width expressed in feet into 340.3 feet.

Example: for a 13-inch band the calibration distance would be 340 divided by 13/12 = 314.1.

* To increase calibration accuracy for a wide outlet spacing, multiply calibration distance by a factor (for example, 2); then, divide Step 8 material collected by the same factor for pounds per acre. For narrow spacings with long calibration distances, divide calibration distance by a factor (for example, 4); then, multiply Step 8 by the same factor for pounds per acre. Keep in mind that application accuracy will decrease when factoring narrow outlet or band spacings.

Band Application

Use the recommended broadcast pesticide rates to make tank mixtures for band applications when calibrating with Procedure B of this method. The number of gallons per acre determined in Step 7 are the gallons that will be applied to each acre of actually treated band.

To determine the gallons of spray mixture required to make a band application on a field, the number of acres that will be in the treated band must be determined. When all treated bands are the same width and all untreated bands are the same width, which is usually the case, the acres in the treated band can be calculated by placing the width of the treated band over the sum of the widths of the treated band and the untreated band, and multiplying this fraction times the number of acres in the field. Example - How many acres will actually be treated in a 30-acre field if a 12-inch band of chemical is applied over the drill of rows spaced 36-inches apart. The treated band width is 12 inches. The untreated band width is (36 inches – 12 inches) = 24 inches. Acres actually treated will be 12 inches divided by (12 inches + 24 inches) times 30 acres equals 10 acres. The amount of mixture required will be 10 times the number of gallons per acre from Step 7. The amount of chemical required will be 10 times the recommended broadcast rate for one acre.
Check rate recommendations carefully as to type of application, broadcast, band or row, and type of material specified, formulated product, active ingredient, etc.

Calculating Formulation Requirements for Active Ingredient Rates.
To determine amount of liquid pesticide required for a rate given in pounds of active ingredient per acre, divide recommended rate by pounds active ingredient per gallon stated on label. Example – Pesticide label states 4 lb active ingredient (AI) per gallon and recommends 1/2 pound AI per acre. Amount of pesticide required: 1/2 lb AI per acre divided by 4 lb AI per gal. = 1/8 gal per acre.

To determine amount of wettable powder required for a rate given in pounds active ingredient per acre, divide recommended rate by percent active ingredient stated on label. Example - Pesticide label states powder is 50% active ingredient. Two pounds of active ingredient is recommended per acre. Amount of pesticide powder required: 2 lbs AI per A divided by 0.5 AI per lb = 4 lb per acre

CALIBRATION OF BACKPACK SPRAYERS 1000 Sq Ft Method

Gary L. Hawkins, Extension Engineer
Glen C. Rains, Extension Engineer

Backpack sprayers are often used to treat ornamental or small areas of turf. Herbicide recommendations are based on amount per acre and amount per 1000 sq ft. Regardless of the type of sprayer used to apply herbicides, the speed, pressure, and nozzle height must be kept constant for accurate application. The backpack sprayer may require some modification so that it is better suited for application. A pressure gauge mounted on the tank side of the shutoff valve will allow continuous monitoring of the tank pressure, which must remain uniform. Optimum pressure control can be achieved by inserting a pressure regulator between the pressure gauge and nozzle. To prevent dripping after the shutoff valve is closed, use a quick, positive pressure shutoff valve or a strainer with a check valve. Nozzle clogging, a problem associated with the use of wettable powders (as well as dry flowable [DF] and water dispersible granular [WDG] formulations) can be reduced by inserting a 50 mesh in-line strainer and keeping the solution constantly agitated. The following is a procedure of 1000 sq ft.

Step 1. Measure the length and width of the test area to be sprayed. Then calculate the area to be covered.

Test Area is: length _____ ft X width _____ ft = _____ sq ft

Step 2. Fill sprayer with water and spray the test area. Record the amount of water to refill the sprayer.

Volume (ounces) per test area _____

Step 3. Find the label rate of material to be applied per 1000 sq ft

Rate _______ per 1000 ft^2

Step 4.

$$\frac{\textit{1000 ft}^2 \textit{ x Volume (ounces) per test area}}{\textit{Test Area (ft}^2\textit{)}} = \textit{Volume (ounces) per 1000 ft}^2$$

Step 5. Calculate the area covered per tank as follows:

$$\frac{\textit{Tank volume (ounces) x 1000 ft}^2}{\textit{Volume per 1000 ft}^2} = \textit{Area covered per tank (ft}^2\textit{)}$$

Step 6. Calculate amount of material to add to tank.

$$\frac{\textit{Area per tank (ft}^2\textit{) x Label rate per 1000 ft}^2}{\textit{1000}} = \textit{Amount to add (rate units)}$$

Solutions derived from the above may need to be converted to a smaller unit in order to accurately measure the pesticide accurately. The following conversion chart will help simplify this problem.

CONVERSIONS:

VOLUME		WEIGHT
gallons x 128	= fluid ounces (fl oz)	$\frac{\text{pounds x 16 wt oz}}{\text{pounds}}$ = weight ounces (wt oz)
pints x 16	= fluid ounces (fl oz)	$\frac{\text{weight ounces x 28.35 g}}{\text{weight ounces}}$ = grams (g)
fl oz x 29.57	= milliliters (ml)	$\frac{\text{weight ounces x 1000}}{\text{weight ounces}}$ = milligrams (mg)
gallons x 4	= quarts (qts)	
quarts x 2	= pints (pts)	
fl oz x 2	= Tablespoons (Tbsp)	
tsp x 3	= Tablespoons (Tbsp)	
tsp x 5	= milliliters (ml)	

An example of using this conversion chart. If the rate calls for 0.25 gallons of material then converting to ounces would be done as follows: 1 gallon has 128 ounces, so multiply 0.25 gallons by 128 to get 32 ounces. So, you would need to measure out 32 ounces for your application. The same thing for a weight. If you need 0.25 pounds, then multiply 0.25 by 16. This is calculated as 0.25 pounds times 16 to get 4 weight ounces of material.

CALIBRATING TURFGRASS SPRAYERS (Gallons per 1000 Sq Ft)

Gary L. Hawkins, Extension Engineer
Glen C. Rains, Extension Engineer

Low-pressure boom sprayers are used frequently for applying chemicals on large areas such as golf courses and recreational areas. Application rates for turf are normally given in gallons per 1000 sq ft. Calibrating a boom sprayer is not as difficult as it sounds. Calibrate your sprayer often to compensate for nozzle wear, pump wear and speed changes.

Calibrate with clean water. Check uniformity of nozzle output across the boom. Collect from each for a known time period. Each nozzle should be within 10 percent of the average output. Replace with new nozzles if necessary. When applying materials that are appreciably different from water in weight or flow characteristics, such as fertilizer solutions, calibrate with the material to be applied. Exercise extreme care and use protective equipment when active ingredient is involved.

Step 1. Determine the Effective Swath Width (W) per Nozzle
For boom spraying, the effective spray width of each nozzle (W) is equal to the distance in inches between two nozzles.

Step 2. Determine Travel Speed (MPH)
To determine the travel speed, measure a known distance. Use fence posts or flags to identify this distance. A distance over 200 feet and a tank at least half full are recommended. Travel the distance determined at your normal spraying speed and record the elapsed time in seconds. Repeat this step and take the average of the two measurements. Use the following equation to determine the travel speed in miles per hour:

$$\textit{Travel Speed (MPH)} = \frac{\textit{Distance (feet)} \times 0.68}{\textit{Time (seconds)}}$$

(0.68 is a constant to convert feet/second to miles/hour)

Step 3. Determine Nozzle Flow Rate (GPM)
With the sprayer parked, operate the sprayer at the same pressure level and catch the output from each nozzle in a measuring jar for one minute (or collect output for half a minute and then double the ounces collected) to determine the nozzle flow rate in ounces per minute (OPM) Then, convert the final average output in OPM to gallons per minute (GPM) using the following equation:

$$\textit{GPM = OPM/128 (1 Gallon = 128 ounces)}$$

Step 4. Determine the Actual Application Rate in Gallons per 1000 sq ft
Use the following equation to determine the gallons per acre application rate:

$$\textit{Gallons per 1000 sq ft} = \frac{136 \times \textit{gpm (per nozzle)}}{\textit{MPH} \times W}$$

GPM: average nozzle flow rate in gallons per minute
MPH: travel speed in miles per hour
W: distance between two nozzles in inches
136 a constant to convert units to gallons per 1000 ft^2

Step 5. Calculate the area covered per tank as follows:

$$\frac{\textit{Tank Volume (gallons)} \times 1000}{\textit{Application Rate (gallons per 1000 } ft^2\textit{)}} = \textit{Area covered per tank } (ft^2)$$

Step 6. Calculate amount of material to add to tank

$$\frac{\textit{Area covered per tank } (ft^2) \times \textit{Material rater per 1000 } ft^2}{1000} = \textit{Amount to add (rate units)}$$

HAND SPRAYER CALIBRATION FOR ORNAMENTAL AND TURF

Gary L. Hawkins, Extension Engineer
Glen C. Rains, Extension Engineer

Hand sprayers are often used to treat ornamental or small areas of turf. The directions on many ornamental pesticide product labels say to "spray until foliage is wet" or perhaps "spray until runoff." Unfortunately, these directions are subject to each applicator's interpretation of what "wet" or "runoff" is.

Recommendations are based on amount per 100 gallons. This is the dilution ratio for the chemical applied. Use the following to convert 100-gallon rate to bed area rate.

1. Measure the length and width of the area to be sprayed. Then calculated the area to be covered.

   Bed Area is: _____ length X _____ width = _____ ft^2

2. Fill sprayer with water and spray the area. Record the amount of water to refill the sprayer.

   Gallons per bed area _______

3. Obtain the rate of material to be applied per 100 gallons. Rate _______

4. $$\frac{\textit{Rate x Gallons per bed area}}{\textit{100}} = \textit{Amount per bed area}$$

5. Calculate the total amount of material to be used for the application (total bed area) as follows:

   $$\frac{\textit{Amount per bed area x Area to be sprayed}}{\textit{Bed area } (ft^2)} = \textit{Amount of material}$$

6. Total solution to prepare is:

   $$\frac{\textit{Gallons per bed area x Area to be sprayed } (ft^2)}{\textit{Bed area } (ft^2)} = \textit{Total Solution}$$

Solutions derived from the above may need to be converted to a smaller unit in order to accurately measure the pesticide accurately. The following conversion will help simplify this problem.

CONVERSIONS:

VOLUME		WEIGHT
gallons x 128	= fluid ounces (fl oz)	$\frac{\text{pounds x 16 wt oz}}{\text{pounds}}$ = weight ounces (wt oz)
pints x 16	= fluid ounces (fl oz)	
fl oz x 29.57	= milliliters (ml)	$\frac{\text{weight ounces x 28.35 g}}{\text{weight ounces}}$ = grams (g)
gallons x 4	= quarts (qts)	
quarts x 2	= pints (pts)	$\frac{\text{weight ounces x 1000}}{\text{weight ounces}}$ = milligrams (mg)
fl oz x 2	= Tablespoons (Tbsp)	
tsp x 3	= Tablespoons (Tbsp)	
tsp x 5	= milliliters (ml)	

An example of using this conversion chart. If the rate calls for 0.25 gallons of material then converting to ounces would be done as follows: 1 gallon has 128 ounces, so multiply 0.25 gallons by 128 to get 32 ounces. So, you would need to measure out 32 ounces for your application. The same thing for a weight. If you need 0.25 pounds, then multiply 0.25 by 16. This is calculated as 0.25 pounds times 16 to get 4 weight ounces of material.

AIRBLAST SPRAYER CALIBRATION — ORCHARD AND VINEYARD

Gary L. Hawkins, Extension Engineer
Glen C. Rains, Extension Engineer

Calibration is the process of measuring and adjusting the gallons per acre of spray actually applied. Sprayers need to be calibrated to meet the coverage needs of the orchards to be sprayed and to facilitate precise dosing of each material. A sprayer should be set up to apply a gallon per acre rate at a desired speed and pressure. In-orchard calibration frequently indicates a need for adjustments to achieve the target gallons per acre.

Speed of travel of a sprayer is a vital factor in obtaining the number of gallons of spray per acre desired. Change in gallons per acre (GPA) applied is inversely proportional to the change in speed. If speed is doubled, the gallons per acre will be halved. Thus, if nozzles have been installed and pressure set to provide a gallon per acre rate at a certain speed, the sprayer should apply the GPA rate at that speed.

To determine the travel speed, measure a known distance. Use fence posts or flags to identify this distance. A distance over 100 feet and a tank at least half full are recommended. Travel the distance determined at your normal spraying speed and record the elapsed time in seconds. Repeat this step and take the average of the two measurements. Use the following equation to determine the travel speed in miles per hour.

$$\textit{Travel Speed (MPH)} = \frac{\textit{Distance (feet)} \times 0.68}{\textit{Time (seconds)}}$$

(0.68 is a constant to convert feet/second to miles/hour)

Calculating Gallons per Minute (GPM) Output

The gallons per minute output required for a sprayer traveling along both sides of each row spraying from one side for a desired gallon per acre rate can be calculated with the following equation:

$$\textit{GPM Required} = \frac{\textit{GPA (required)} \times \textit{MPH (determined)} \times \textit{Row Spacing (feet)}}{\textit{990 (spraying one side)}}$$

(If one pass is made between rows spraying from both sides of the sprayer, use 495 as constant.) GPA = Gallons per Acre MPH = Miles per Hour

To check actual GPM output:

1. Fill sprayer with water. Note the level of fill. If a material with considerably different flow characteristics than water is to be sprayed fill the sprayer with this material.
2. Operate the sprayer at the pressure that will be used during application for a measured length of time. A time period of several minutes will increase accuracy over a time period of 1 minute. A suggested time is 5-10 minutes.
3. Measure the gallons of liquid required to refill sprayer to the same level it was prior to the timed spray trial with the sprayer in the same position as when it was filled initially. The actual GPM can be calculated as follows:

$$\textit{GPM (actual)} = \frac{\textit{Gallons to refill sprayer tank}}{\textit{Minutes of spray time}}$$

4. Calculate the GPA being applied spraying from one side on both sides of row by the sprayer.

$$\textit{GPA (actual)} = \frac{\textit{GPM (actual)} \times \textit{990 (spraying one side)}}{\textit{MPH} \times \textit{Row Spacing (feet)}}$$

If the actual GPA is slightly different from the required GPA, the actual GPA can be increased or decreased by increasing or decreasing spray pressure on sprayer models that have provisions for adjusting pressure. Only small output changes should be made by adjusting pressure. Major changes in output should be done by changing nozzles or ground speed.

Nozzle Setup

Nozzle arrangement and air guide or director vane settings should place most of the spray in the top half of the plants, where most of the foliage and fruit are located. Air blast sprayers are typically set up to apply 2/3 to 3/4 of the spray to the top half, and 1/3 to 1/4 to the bottom half. This targeted spraying is accomplished by placing more or larger nozzles on manifolds in the area that supplies spray to the upper half of trees and setting the air directors on the fan outlet to direct the air stream accordingly. Plant growth and target pest habits should be considered in determining the setup for specific applications.

PESTICIDE RESISTANCE MANAGEMENT

Milton D. Taylor, Coordinator
Pesticide Safety Education Program

Pest resistance is the genetic process enabling pest populations (insects, mites, fungi, bacteria, weeds) to change so they survive previously lethal pesticide exposures. Commonly, this is either by physiological changes that facilitate detoxification of specific toxins or behavioral modification such as avoidance of exposure. Pest resistance is a major challenge wherever pesticide use is common and resistance management recommendations are ignored by applicators. Genetic changes to detoxification pathways can render specific toxins useless against a pest. Cross resistance to materials of similar chemistry, those that share the same toxic mode of action, can often compromise multiple products. Thus, resistance in peach brown rot to one triazole fungicide (MOA FRAC 3) or codling moth resistance to one organophosphate insecticide (MOA IRAC 1B) very often means other materials in those chemical classes will also be ineffective. Pests acquire pesticide resistance when frequent or repetitive use eliminates most individuals in a population that are susceptible to a toxin. A very low frequency of abnormal, genetically controlled physiological traits are normally present in most pest populations, but because individuals expressing these traits are maladapted to successfully compete under normal conditions, these traits remain rarities. However, if individuals bearing these normally inconsequential, non-competitive traits can survive frequent pesticide use, they will prosper when pesticide use favors their survival. Over generations, the genetics of entire populations of heavily sprayed pests will shift, so that resistant or tolerant individuals become common. The most effective means of mitigating the acquisition of pest resistance is through integrated pest management (IPM), which limits pesticide use to as-needed sprays and recommends frequent rotation of pesticide products with differing modes of action. IPM limits pesticide use to times when other factors, such as adverse weather or mortality caused by natural enemies such as parasites, predators, or diseases of the pests, do not provide sufficient pest control. IPM is commonly complemented by resistance management in the form of rotation of effective pesticides that are of unlike modes of action. Resistance Action Committees, composed of select toxicologists interested in mitigating or slowing the development of pesticide resistance, have assigned numerical designations to materials that share a common mode of action. If users will alternate the use of effective materials that have unlike numbers, they will rotate modes of action, which typically slows the development of pesticide resistant pests. The individual committees are designated as Insecticide/Miticide Resistance Action Committee (IRAC), Fungicide Resistance Action Committee (FRAC) and Herbicide Resistance Action Committee (HRAC). This book uses “Mode of Action” rather than the individual acronyms to simplify and standardize the presentation of this information.

PROTECT HONEY BEES FROM PESTICIDES

Keith S. Delaplane, Extension Entomologist

Roughly one-third of the human diet can be traced to bee pollination. Bees pollinate an estimated 16% of the world's flowering plants. The annual value of bee pollination in the United States is more than $15 billion and for Georgia, in particular, $367 million. Georgia ranks second nationally in queen bee and packaged bee production, and 14th in honey production.

Many pesticides are extremely hazardous to honey bees, but damage can be minimized if the pesticide user and the beekeeper cooperate and take proper precautions.

THE PESTICIDE USER'S ROLE

1. Use pesticides only when needed.
2. Select one of the least hazardous pesticides that will effectively control target pests, especially on flowering plants that attract bees.
3. Use the least hazardous method of application. Granules are usually harmless to honey bees. Liquid applications drift less than dusts and are less likely to kill bees in nearby untreated areas. Whenever possible, minimize drift by applying pesticides with ground-application equipment rather than with airplanes.
4. Do not apply pesticides when honey bees are active in the field. Applications of effective materials of short residual are best. Late evening or night applications are least likely to kill bees.
5. Do not apply insecticides when crops are in bloom. In orchards, manage orchard-floor vegetation to minimize bloom of orchard-floor cover species. Minimize use of any pesticides during bloom as even non-insecticides may have adverse but sub-lethal effects on pollinators.
6. Avoid pesticide drift into apiaries or areas where crops or wild plants are flowering. With crops that require heavy pesticide applications, plant them in non-sensitive areas if possible.
7. Notify nearby beekeepers several days before you apply a pesticide.

THE BEEKEEPER'S ROLE

1. Whenever possible, locate colonies away from areas of heavy pesticide use.
2. Conspicuously post your name, address, email, and phone number at your apiary and tell nearby farmers where your hives are located.
3. Know which pesticides are commonly used in your area and be prepared to confine or remove your bees if you are notified that a pesticide will be applied. Commonly used pesticides are grouped according to hazard in the following list.

If you cannot move hives in time to avoid a pesticide application, you can cover each hive with a plastic sheet at night and in the early morning to confine the bees and protect them from short-residual pesticides. However, heat builds up rapidly once the plastic is exposed to the sun and it must be removed. Wet burlap, can be used as an alternative for a day or more. This may be impractical for large numbers of hives. Colonies that are repeatedly exposed to pesticides in Groups I or II of the list on page 49 should be relocated.

COMMONLY USED PESTICIDES GROUPED ACCORDING TO THEIR RELATIVE HAZARDS TO HONEY BEES[1]

Group I - Hazardous	Group II - Moderately Hazardous	Group III - Relatively Nonhazardous	
abamectin (Agri-Mek)	*aldicarb* (Temik)	*acetamiprid* (Assail)	*fenbutatin-oxide* (Vendex)
acephate (Orthene, Address)	*carbaryl* (Sevin XLR formulation only)	*allethrin* (Pynamin)	*fenhexamid* (Elevate)
avemectin (AVID)	*carbophenothion* (Trithion)	*amitraz* (Mitac)	*ferbam*
azinphosmethyl (Guthion)	*chlorethoxyfos* (Fortress 5G)	*amitrole*	*fluvalinate* (Spur)
bifenthrin (Capture)	*coumaphos* (Co-Ral)	*azadirachtin* (Align)	*folpet* (Phaltan)
carbaryl (Sevin, Sevin XLR-Plus)	*cypermethrin* (Ammo)	*azoxystrobin* (Abound)	Garlic Barrier
chloropyrifos (Dursban, Lorsban)	*cyromazine* (Trigard)	*Bacillus thuringiensis* (Biobit, DiPel, Full-Bac, Javelin, MVP)[3]	genite 923
clofentezine (Apollo)	*diatomaceous earth* (Diatect)	*Beauveria* (Mycotrol)	*glyodin* (Glyoxide)
cyfluthrin (Baythroid)	*disulfoton* (Di-Syston)	*benomyl* (Benlate)	*kaolin* (Surround)
cyhalothrin (Warrior)	*DSMA*	*binapacryl* (Morocide)	*malathion* (Malathion G)
clothianidin	*emamectin benzoate* (Proclaim)	*bordeaux* mixture	*mancozeb* (Dithane M-45)
cypermethrin (Ammo)	*ethoprop* (Mocap)	*bromoxynil*	*maneb* (Dithane M-22)
deltamethrin (Decis)	*fonofos* (Dyfonate)	*capsaicin* (Hot Pepper Wax)	*MCPA*
diazinon (Diazinon)	*malathion*	*captan*	*metaldehyde* (Metaldehyde Bait)
dichlorvos (DDVP, Vapona)	*methyl demeton* (Metasystox)	*carbaryl* (Sevin G, Bait G)	*methoxychlor* (Marlate)
dicrotophos (Bidrin)	*MSMA*	*carbofuran* (Furadan G)	*metiram* (Polyram-F)
dimethoate (Cygon, Dimethoate, Rebelate)	*neem* (Azatin, Neemix)	*chloramben*	*monuron* (Telvar)
emamectin (Proclaim)	*oxydemeton-methyl* (Metasystox R)	*chlorbenzide* (Mitox)	*myclobutanil* (Rally)
endosulfan (Thiodan)	*paraquat*	*chlorobenzilate* (Acaraben)	*nabam* (Parzate)
esfenvalerate (Asana)	*perthane*	*chlorothalonil* (Bravo)[4]	*nemagon*
fenpropathrin (Danitol)	*pymetrozine* (Fulfill)	*copper* compounds (Kocide)	*nicotine sulfate*
fenthion (Baytex)	*pyriproxyfen* (Esteem)	*copper oxychloride* sulphate	*oxythioquinox* (Morestan)
fipronil	*ronnel* (Co-Ral, Korlan)	*copper* 8-*quinolinolate*	*propargite* (Omite)
hexythiazox (Savey)	*spinosad* (Spin Tor)	*copper sulfate* (Monohydrated)	*pyrethrum* (natural)
imidacloprid (Provado)	*temephos* (Abate)	*cryolite* (Cryolite, Kryocide)	*pyrimidinamine* (Vangard)
indoxacarb (Avaunt)	*terbufos* (Counter)	*cyromazine* (Trigard)	*rotenone*
lambda-cyhalothrin (Warrior)	*thiamethoxam* (Actara, Platinum)	*dalapon*	*ryania*
methamidophos (Monitor)	*thiodicarb* (Larvin)	*dazomet* (Mylone)	*silvex*
methidathion (Supracide)		*demeton* (Systox)	*simazine* (Princep)
methiocarb (Mesurol)		*dexon*	soap (M-Pede)
methomyl (Lannate)		*diazinon* (Diazinon G)	*sulfur*
methyl parathion (Penncap-M)		*dicamba* (Banvel D)	*tebufenozide* (Confirm)
naled (Dibrom)[2]		*dichlone* (Phygon)	*TDE* (Rhothane)
oxamyl (Vydate)		*dicofol* (Kelthane)	*tetradifon* (Tedion)
permethrin (Ambush, Pounce)		*diflubenzuron* (Dimilin)	*thioquinox* (Eradex)
phorate (Thimet EC)		*dimite* (DMC)	*thiram* (Arasan)
phosmet (Imidan)		*dinocap* (Karathane)	*toxaphene*
phosphamidon (Dimecron)		*diquat*	*trichlorfon* (Dylox)
propoxur (Baygon)		*disulfoton* (Di-Syston G)	*trifloxystrobin* (Flint)
resmethrin (Synthrin)		*dodine* (Cyprex)	*zineb* (Dithane)
tebufenozide (Confirm)		*dyrene*	*ziram*
thiamethoxam		*endothall*	*2,4-D*
tralomethrin (Scout)		*EPTC* (Eptam)	*2,4-DB*
zeta-cypermethrin (Fury, Mustang)		*ethion* (Ethion)	*2,4,5*-T
		ethoprop (Mocap G)	

[1] List derived in part from Johansen, C.A. and Mayer, D.F. Pollination Protection. 1990, Wicwas Press; Bulletin E-5 3-W, Hunt, G.J., Purdue University; Environmental Entomology 33(5):1151-1154.

[2] *Naled* (Dibrom) has short residual activity and kills only the bees contacted at time of treatment or shortly thereafter. It is usually safe to use when bees are not in flight; it is not safe to use around colonies.

[3] Not all *Bacillus thuringiensis* insecticides are safe for bees. The label for XenTari® (Valent BioSciences), with active ingredient *B. thuringiensis aizawai*, reads "This product is highly toxic to honey bees exposed to direct treatment. Do not apply this product while bees are actively visiting the treatment area."

[4] Beekeepers should manage hives to avoid exposure to *chlorothalonil*. Data from 2010 suggest that chlorothalonil fungicide expresses toxicity in honey bee brood in the context of crop applications at time of bloom. Additionally, lethal synergies occur between this product and the miticide *fluvalinate* used to control varroa mite in bee hives.