NebGuide

University of Nebraska–Lincoln Extension, Institute of Agriculture and Natural Resources

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G2044

Calibration of Sprayers (Also Seeders)

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Methods and calculations for calibrating sprayers and seeders for accurate in-field application plus a section on converting weights and measures.

Applying the correct rate of a product is an important part of obtaining good results with both seeders and pesticide sprayers. With seeders too little seed reduces crop yields and increases weeds while too much seed increases costs and may reduce yields. With a pesticide application, too little product can mean poor control, while too much can mean crop injury, extra costs, and possible residue on the crop and/or carryover.

Many methods can be used to calibrate sprayers, including the ounce calibration and formula-based methods. With the ounce calibration method, 1/128 of an acre is sprayed and the spray is collected. When measured in ounces, the amount collected would be equal to the number of gallons applied per acre since there are 128 ounces in a gallon. (For further information on this method, see UNL Extension NebGuide *Fine-Tuning a Sprayer with the "Ounce" Calibration Method*, G1756.) Other methods involve using formulas which need to be remembered or recorded for easy use. These methods also may require converting some of the information you have.

The methods discussed in this NebGuide are simple relationships and do not require remembering formulas. However, you do need a general understanding of cross multiplication. The important thing is to be consistent: If you put an item on top of an equation on one side, the same item also goes on the top on the other side.

Factors Affecting Rates

Three factors determine sprayer application rate:

1. Speed
2. Nozzle spacing
3. Nozzle output (determined by orifice size, pressure, and density of spray solution)

Where:

Speed = Length or distance covered divided by time
Nozzle spacing = Width
Nozzle output = The quantity applied/unit time

The following diagram shows how these three factors are related:

Speed = length or distance covered divided by time

Nozzle spacing (width) | Nozzle output = the quantity applied/unit time

For example, to determine speed:
1 mile per hour (mph) is:
1 mile (5,280 ft) in 1 hour (60 minutes)

$$\text{Or } 1 \text{ mph} = \frac{5{,}280 \text{ ft/hour}}{60 \text{ min/hour}} = 88 \text{ ft/min}$$

Problem 1. Determine speed in mph.

If we travel 440 feet (ft) in 30 seconds (sec), what is our speed in mph?

The objective is to determine the distance traveled in 60 seconds (1 minute) and divide by 88 (88 feet/minute is equal to 1 mph).

$\frac{30 \text{ sec}}{440 \text{ ft}} = \frac{60 \text{ sec}}{D}$ (D is the distance we are solving for in the equation)

We cross multiply to find the value of D
$30 D = 60 \times 440$
$30 D = 26{,}400$

$$D = \frac{26{,}400}{30}$$

D = 880 ft/60 sec

Since every 88 ft traveled/60 sec (1 min) is equal to 1 mph, we divide 880 by 88 to get 10 mph.

Problem 2. Determine speed in mph.

If we travel 297 feet in 27 seconds, what is our speed?

$$\frac{27 \text{ sec}}{297 \text{ ft}} = \frac{60 \text{ sec}}{D}$$

$27 D = 60 \times 297$
$27 D = 17{,}820$

$$D = \frac{17{,}820}{27}$$

D = 660 ft/60 sec

Divide by 88 since 1 mph = 88 ft/60 sec (1 min)

$\frac{660}{88} = 7.5$ mph

Problem 3. Determine speed in mph.

If we travel 660 feet in 1 minute and 15 seconds, what is our speed?

First, convert 1 minute and 15 seconds to seconds: 60 + 15 = 75 seconds

$$\frac{75\text{ (sec)}}{660\text{ (ft)}} = \frac{60\text{ (sec)}}{D}$$

$75\,D = 39{,}600$
$D = 528$ ft/60 sec

Divide by 88 since 1 mph = 88 ft/60 sec (1 min)

$\frac{528}{88} = 6$ mph

Problem 4. Determine rate/acre.

If the sprayer is moving at 6 mph, the distance covered in one minute is 528 feet (6 mph x 88 ft/min = 528 feet).

To determine the area you cover with one nozzle in one minute if your sprayer has a 30-inch nozzle spacing:

30 in (2.5 ft) $\frac{\text{Distance traveled } 6 \times 88 = 528 \text{ ft/min}}{\text{Area sprayed} = 1{,}320 \text{ sq ft } (2.5 \text{ ft} \times 528 \text{ ft/min})}$

Collect the output of several nozzles and determine the average output per nozzle. All nozzles should be within 10 percent of the manufacturer's rating for that nozzle. For example an XR11003 delivers 0.3 gpm at 40 psi. If it delivers more than 0.33 gpm or 42.24 (128 x .33) ounces/min at 40 psi, the nozzle should be replaced. Any nozzle delivering 5 percent above or below the average delivery rate for all the nozzles should be replaced.

For this example, the average nozzle output is 32 oz per minute or
32 (oz/min) ÷ 128 (oz/gallon) = 0.25 gpm

What is the rate per acre? One way to calculate application rate without remembering a formula is to use a relationship: The amount applied and the area sprayed per minute are the same as the amount applied and the area sprayed per acre.
R = gal/acre

	Minute Box: Distance 6 x 88 = 528 ft		Acre Box
Nozzle Spacing 30 in ÷ 12 = 2.5 ft	0.25 gpm	=	R
	528 x 2.5 = 1320 sq ft		43,560 sq ft

From minute box $\frac{0.25}{1320} = \frac{R}{43{,}560}$ From acre box

$1320R = 10{,}890$ (0.25 x 43,560)
$R = 8.25$ gal/acre

Problem 5. Determine the acres sprayed per minute.

Travel distance in one minute = 616 ft
Nozzle spacing = 30 in (20 nozzles on sprayer)
Nozzle output = 64 oz/minute

What is travel speed? 616 ÷ 88 = 7 mph (Remember 88 ft/min = 1 mph)

What is sprayer width? 20 nozzles x 2.5 ft (30-inch spacing) per nozzle = 50 ft

What is application rate? $\frac{64 \text{ oz/min}}{128 \text{ oz/gal}} = 0.5$ gpm

	Minute Box: Distance 616 ft		Acre Box
30-inch nozzle spacing (2.5 ft)	64 oz or 0.5 gpm	=	R
	1,540 sq ft		43,560 sq ft

$\frac{0.5}{1{,}540} = \frac{R}{43{,}560}$

$1540\,R = 21{,}780$
$R = 14.14$ gal/acre

To determine the area covered by the sprayer in one minute:
1,540 sq ft/nozzle/minute
20 nozzles

1,540 x 20 ÷ 43,560 sq ft/acre = 0.71 acre/minute

Problem 6. Determine nozzle size needed to achieve the operational goal.

Sprayer speed = 7 mph
Nozzle spacing = 20 inches
Application rate desired = 17 gpa
Nozzle flow rate = F

	Minute Box: 7 x 88 = 616 ft		Acre Box
Nozzle Spacing $\frac{20 \text{ in}}{12 \text{ in/ft}} = 1.67$ ft	F = gpm	=	17 gpa
	1,029 sq ft		43,560 sq ft

$\frac{F}{1{,}029} = \frac{17}{43{,}560}$

$43{,}560\,F = 17{,}493$
$F = 0.40$ gpm or XR8004* at 40 psi

If we need 0.40 gpm, by design an XR8005* will give 0.5 gpm at 40 psi. Output varies by the square root of the pressure.

For example: $\sqrt{40 psi} = 6.32$ psi
$= 2$
$\sqrt{10\ psi} = 3.16$ psi

Raising the pressure from 10 to 40 psi (4 times $\sqrt{4} = 2$) doubles output.

Therefore we need to reduce output to 0.40 gpm which is 80 percent of the 0.5 gpm that an XR8005 puts out at 40 psi.

$\sqrt{40} = 6.32 \times 0.8 = 5.056$

$\sqrt{P}$

To solve for "P" take the result multiplied by itself.
5.056 x 5.056 = 25.6 psi
an XR8005 at 25.6 psi will give you 0.40 gpm

*Selected from *TeeJet Nozzle Booklet* by Spraying Systems.

Problem 7. Calibrate a hand sprayer.

First fill sprayer with water to a known level, a mark you can later refill to accurately. (Tip: It's best to spray a test area over concrete so you can see the evenness of application.)

Spray test area 100 sq ft = 10 ft x 10 ft
or 250 sq ft = 10 ft x 25 ft
or 500 sq ft = 10 ft x 50 ft or 20 ft x 25 ft

Refill sprayer to same level as before, measuring amount of water it takes to refill sprayer.

If the pesticide recommendation is for 2 liquid ounces of product per 1,000 sq ft, the amount to include per 1,000 sq

ft would be 1/4 cup or 4 tablespoons or 12 teaspoons. (See *Weights and Measures Conversions* on page 4.)

If during the test, 28 oz of water were applied over 250 sq ft, how much water and pesticide should be added to a 3-gallon sprayer?

The amount of water you applied in test area: $\frac{28 \text{ oz}}{250 \text{ sq ft}} = \frac{V \text{ for volume}}{1{,}000 \text{ sq ft}}$ How much water you will apply per 1,000 sq ft

250 V = 28,000
V = 112 ounces or ÷ 32 (oz/qt) =

3.5 qt of water per 1,000 sq ft

This indicates that 2 oz of pesticide should be added for every 3.5 qt of sprayer capacity.

With a 3-gallon sprayer, 12 qt (3 x 4 qt/gal) of water should be added to the sprayer tank.

$$\frac{2 \text{ oz}}{3.5 \text{ qt}} = \frac{P \text{ for Pesticide}}{12 \text{ qt}}$$

3.5 P = 24
P = 6.86 oz or 0.86 cup (8 oz/cup)

6.86/8 = 0.86 cup — This is the amount of pesticide to add to a 3-gallon sprayer

Problem 8. Determine the density of spray solution.

The rate at which a fluid flows through a spray orifice varies with its density. Since all the tabulations are based on spraying water, which weighs 8.34 lb per U.S. gallon, conversion factors must be used when spraying solutions which are heavier or lighter than water. To determine the proper size nozzle for the solution to be sprayed, first multiply the desired GPM or GPA of solution by the water rate conversion factor. The conversion factors are the square root of specific gravity. (See *Weights and Measures Conversion* chart on page 4 for some common fertilizers.)

For example, the specific gravity of 28% nitrogen, which weighs 10.65 lb/gal, is:

$$\frac{10.65 \text{ (Wt of 28-0-0/gal)}}{8.34 \text{ (Wt of water/gal)}} = 1.28 \text{ specific gravity}$$

Conversion factor for 28-0-0 fertilizer or 28% nitrogen is

$\sqrt{1.28} = 1.13$

Weight of Solution	*Specific Gravity*	*Conversion Factors*
7.0 lb per gallon	0.84	0.92
8.0 lb per gallon	0.96	0.98
8.34 lb per gallon - water	1.00	1.00
9.0 lb per gallon	1.08	1.04
10.0 lb per gallon	1.20	1.10
10.65 lb per gallon - 28% nitrogen	1.28	1.13
11.0 lb per gallon	1.32	1.15
11.06 lb per gallon - 32% nitrogen	1.33	1.15
12.0 lb per gallon	1.44	1.20
14.0 lb per gallon	1.68	1.30

Example of using the conversion factor:

Desired application rate is 20 GPA of 28% N.
GPA (solution) x Conversion factor = GPA (water)
20 GPA (28%) x 1.13 = 22.6 GPA (water)
A nozzle size should be selected to supply 22.6 GPA of water at the desired pressure, speed, and nozzle spacing.

Problem 9. Determine the density of a spray solution.

In this example, the following has been recommended for an ecofallow corn field:

75 lb of nitrogen from 28% UAN
Density of 28% N = 10.65 lb/gal
10.65 x .28 = 2.982 lb N/gal

$$\frac{75 \text{ lb N}}{2.982 \text{ lb N/gal}} = 25.15 \text{ gal of 28\% solution}$$

Ingredient	*Amount*	*Gallons*
28% Nitrogen	75 lb N	25.151
Balance Pro	2.0 oz	0.016
Fultime	2.25 qt	0.563
Gramoxone Extra	2 pt	0.250
Crop Oil Concentrate	1 qt	0.250
2,4-D 6 LVE	1/2 pt	0.063
		26.293 or 26.3 gal/acre

To determine how this will spray out and what gallonage of water is needed to get 26.3 gal/acre of this spray solution, three steps are required:

1. To determine specific gravity weigh an equal amount of the spray solution and an equal amount of water.

S.S.	Water
13.08 lb	10.3 lb

To determine specific gravity weight of spray solution:

$$\frac{13.08 \text{ lb (wt of spray solution)}}{10.3 \text{ (wt of water)}} = 1.27 \text{ specific gravity}$$

2. Determine conversion factor $\sqrt{1.27} = 1.13$
3. Determine the quantity of water to calibrate sprayer:
   Spray Rate x Conversion Factor = Water Amount Equivalent
   26.3 gal/acre x 1.13 = 29.6 gal/acre
   Now you need to calibrate the equipment to apply 29.6 gal/acre of water.

Problem 10. Calibrate a seeder.

How may pounds of seed are needed to plant 18 seeds/ft in a row with 10-inch spacing. Seed size is 15,000 seeds/lb and seed is collected for 500 ft.

To determine pounds of seed needed per acre:

$\frac{12 \text{ in/ft}}{10 \text{ in/row}} = 1.2$ 1.2 x 43,560 sq ft/acre = 52,272 ft of row/acre

52,272 x 18 seeds/ft row = 940,896 seeds/acre ÷ 15,000 seeds/lb = 62.7 lb/acre

Determine area seeded with one opener on one acre:

10 inches per row or $\frac{10 \text{ in}}{12 \text{ in/ft}} = 0.83$ ft

Test Box 500 ft long		Acre Box
Wt for weight of seed calibrated	=	62.7 lb seed/acre
415 sq ft (500 x .83)		43,560 sq ft

Then cross multiply:

$$\frac{Wt}{415} = \frac{62.7}{43{,}560}$$

43,560 Wt = 26,020.5 (62.7 x 415)
Wt = 0.6 lb/opener or 9.6 oz/opener

Weights and Measures Conversion

Weight

16 ounces = 1 lb = 453.6 grams
1 gallon water = 8.34 lb = 3.78 liters
1 short ton = 2,000 lb
1 long ton = 2,240 lb
1 cubic foot water = 62.4 lb

Liquid Measure

1 fluid ounce = 2 tablespoons = 29.57 milliliters
1 tablespoon = 3 teaspoons = 14.79 milliliters
1 cup = 16 T = 8 oz = 236.583 milliliters
16 fluid ounces = 1 pint = 2 cups
8 pints = 4 quarts = 1 gallon

Dry Measure

1 ounce = 28.3495 grams

Length

1 inch = 2.54 centimeters
3 feet = 1 yard = 91.44 centimeters
16.5 feet = 1 rod
5,280 feet = 1 mile = 1.61 kilometers
320 rods = 1 mile

Area

9 square feet = 1 square yard
43,560 square feet = 1 acre = 160 square rods
1 acre = 0.405 hectare
640 acres = 1 square mile
1 hectare = 2.47 acres

Speed

88 feet per minute = 1 mph
1 mph = 1.61 km/hour
1 mph = 0.477 meter/second

Volume

27 cubic feet = 1 cubic yard
1 cubic foot = 1,728 cubic inches = 7.48 gallons
1 gallon = 231 cubic inches
1 cubic foot = 0.028 cubic meters
Volume of sphere = D^3 x 0.5236

Common Abbreviations and Terms Used

GPM = gallons per minute
GPA = gallons per acre
psi = pounds per square inch
mph = miles per hour
RPM = revolutions per minute
GPH = gallons per hour
FPM = feet per minute
T = tablespoon
t = teaspoon

Circles

Diameter x 3.1416 = circumference
$Radius^2$ x 3.1416 = area

Spraying Systems Droplet Size in Microns

Very Fine = 153 and less
Fine = 154 - 241
Medium = 242 - 358
Coarse = 359 - 451
Very coarse = 452 - 740
Extensively coarse = 741 +

Fertilizer Facts

Pounds per gallon of liquid fertilizer at 60°F

10-34-0	11.40
11-37-0	11.60
7-21-7	11.00
28-0-0	10.65
28-0-0	10.65
32-0-0	11.06
82-0-0	5.15
12-0-0-26	11.50

Comparable Concentrations

1 ppm = 1 second in 12 days or 0.013 ounces in 100 gallons
or about 8/10 of 1 teaspoon in 1,000 gallons
1 ppb = 1 second in 32 years or 0.013 ounces in 100,000 gallons
or about 8/10 of 1 teaspoon in 1,000,000 gal
1 ppt = 1 second in 320 centuries
1 pint of water in ocean = 5,000 molecules in pint of water
1 psi = 2.31 feet
1 foot of lift of water = 0.433 psi
452 gpm = 1inch/1 acre/1 hour

Grain Information

	Lb/bu	*Moisture %*
Corn	56	15.5
Soybeans	60	13.0
Grain sorghum	56	14.0
Wheat	60	13.5
Sunflower	25	10.0

Cu ft x 0.8 = bushel of grain
Cu ft x 0.4 = bushel of ear corn

1 horsepower = 550 ft lb/second
= 33,000 ft lb/minute
= 746 watts

This publication has been peer reviewed.

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