Cornell University Cooperative Extension

Forest Connect

Supporting Sustainable Management of Private Woodlands

An Extension Publication of the Department of Natural Resources, New York State College of Agriculture and Life Science, a Statutory College of the State University at Cornell University, Ithaca, New York

Mixing herbicides

– starting and ending concentrations

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Interfering plants can complicate the plans of woodland owners and foresters to regenerate desirable trees species, or otherwise enjoy the benefits of their investment (Figure 1). In some circumstances mechanical or organic methods can be used to control interfering plants. In other circumstances chemical control, alone or integrated with a mechanical treatment, may be the most cost effective and efficient strategy. Herbicides, a type of pesticide used to control plants, are important tools for woodland management if they are used correctly. Herbicides that are purchased in a concentrated form need to be diluted before use. While correct herbicide mixing is an essential part of safe and effective use, the process of converting a concentrated form to a correct dilution can be a daunting task.

Correct mixing is an important consideration for all modes and methods of herbicide applications, whether foliar, injection, basal bark or cut-stump. The basic process is that a concentrated product is diluted in a liquid such as water. The mixing process is the same for all carriers. The question becomes how much product and how much of the carrier are needed; the answer depends on the final volume of mixture, called the formulation and the amount of active ingredient (a.i.) in the concentrate that is recommended for the treatment. Some terms in this article may be unfamiliar to some readers; key terms are defined here, and more information about forest pesticides is available at the Penn State Forest Vegetation Management website at http://extension.psu.edu/natural-resources/forests/vegetation-management. There are

Figure 1. Ferns are native to our woodlands and can be attractive as a uniform ground cover. However, in efforts to regenerate desirable native species they can interfere because of their dense shade, thick roots, and attractive habitat for seed predators

also good background webinars on the correct use of herbicides in the forest at www.youtube.com/ForestConnect Labels of pesticides available for use in NY can be found and downloaded from www.dec.ny.gov/nyspad/products.

Using the correct concentration of an herbicide is an important part of Integrated Vegetation Management (IVM), also sometimes called Forest Vegetation Management. The herbicide label specifies the maximum concentration, and exceeding that concentration is illegal and a waste of the product. Similarly, a mixture that is too dilute may waste the product if the concentration is insufficient to control the target plant. Refer to the product label or fact sheets by Cooperative Extension or other reputable organizations to identify the best concentration for the season and the target. Note that in New York, it is legally permissible for herbicide treatments in woodlands, which are considered a type of agricultural treatment, to use a less dilute concentration than the amount specified on the label, but it is never legal to use a higher concentration than specified on the label.

The correct concentration of product to use is prescribed based on the label by someone who is familiar with pesticide use. The correct concentration depends on the season and the treatment technique. For example, a prescription to treat beech in the summer might specify an herbicide treatment to foliage with a formulation that uses a glyphosate-based product containing 2% of the product mixed in water plus a surfactant. Conversely, a prescription to treat beech in late fall might specify an herbicide treatment that uses a glyphosate-based product delivered via hack-n-squirt, drill-n-fill, or cut-stump, with the formulation containing 50% or 75% of the product mixed in water.

In discussions of how to prepare a formulation, it is important to clarify if the "percentage" refers to the dilution of the product or the dilution of the active ingredient in the formulation. For example, there are glyphosate products that can be purchased with concentrations of the active ingredient that range from less than 3% to more than 50% (Figure 2). Using products with a.i. concentrations of 3% and 50% as examples, a dilution of equal volumes of water and product (written 1:1) would be a 50% product dilution because there is 50% water

An Abbreviated Glossary of Terms

Active ingredient – Abbreviated "a.i.", refers to the amount of the chemical components in the "product" (see definition below) that act on the target organism. The product may also include a carrier (if pre-mixed) and inert ingredients.

Carrier – the herbicide is often obtained as a product in concentrated form that needs to be diluted before use. The liquid that dilutes the product and carries the active ingredient into the plant is the carrier. Acceptable carriers are specified on the product label and might include water, vegetable oil and diesel fuel.

Formulation – the formulation is the combination of the product and the carrier. This is the material that is applied to the target plant.

Label – every pesticide has a label, written documentation, that describes the chemistry of the pesticide, safety equipment and protocols, target organisms that can be controlled, and how to mix and apply the pesticide. The use of a pesticide legally and contractually binds the user to the details of the label, so users should read and follow the label.

Product – the chemical as it comes from the purchased container. Some people may call this the "concentrate." In some cases the product is pre-mixed to include the carrier and is formulated as ready for use. Products that are pre-mixed are at the correct dilution and require no further manipulation before use.

Treatment – any manner of applying the herbicide to vegetation. More generally, any manipulation of vegetation.

and 50% product. However, this equal-volume formulation would be an a.i. dilution to 1.5% and 25%, respectively, because half of 3% is 1.5% and half of 50% is 25%. These details are important, and should be referenced as a product dilution or active ingredient dilution.

Unless the product is premixed, all labels include a table that specifies the quantities of the product to mix with the carrier (Figure 3). The details of this table, or any table, are specific to that particular product and are not transferrable to the next product you use. Although the mixing table usually has options for all common formulations, it is useful to know the simple math necessary to calculate the dilutions of product to formulation.

It is possible to calculate the dilutions using this formula:

Formula 1: $C_1V_1 = C_2V_2$

In this formula "C" is for concentration and "V" is for volume. The "1" and "2" are the starting and ending amounts. So, for example, C_1 is the initial concentration of product and C_2 is the final concentration that is applied to the target plant. The C_1, V_1 and C_2, V_2 are the four variables of the formula. If we know three of the four variables, we can solve for the fourth variable. The concentrations will usually be a %, and the starting and final volumes will need to be in the same units. Volumes are sometimes a challenge because the final volume (V_2) will often be in gallons and the initial volume (V_1) would often be in ounces. Because we often want to know the initial volume, V_1, it is best to convert the final volume, V_2, into the units of the measuring device you will use. I use a Pyrex mixing cup dedicated for this task (don't borrow mixing utensils from the kitchen!), and thus convert the volume of my spray tank to either ounces or milliliters.

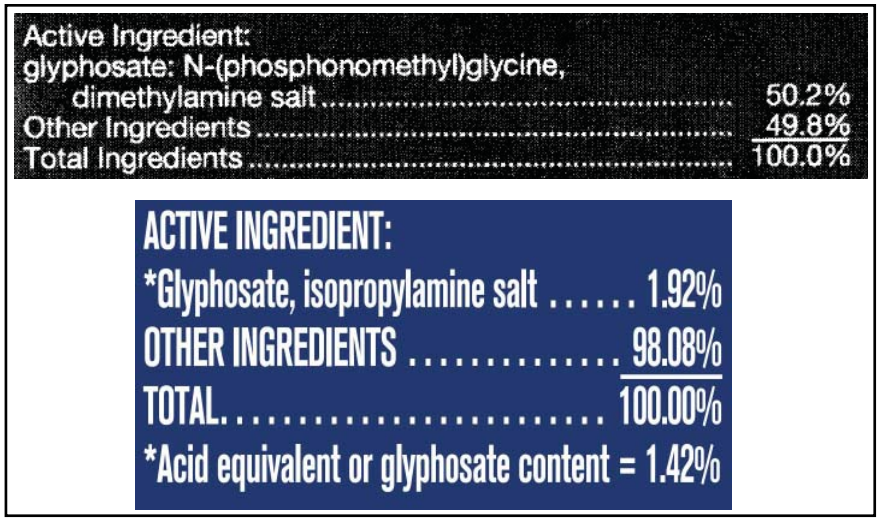

Figure 2. Each herbicide label will specify the concentration of active ingredient (a.i.) within the product. These two labels illustrate the range of a.i. of glyphosate in two commonly available products. The label will describe how to make several common dilutions of the product, but discussion of treatment needs to include a statement of the amount of active ingredient in the formulation.

Mixing for Hand-held Sprayers

Prepare the desired volume of spray solution by mixing the amount of this product in water as shown in the following table:

Spray Solution

Spray Concentration	Amount of This Product for Desired Volume:		
(percent)	1 gal	25 gal	100 gal
0.5%	2/3 fl oz	1 pt	2 qt
0.75%	1 fl oz	24 fl oz	3 qt
1.0%	1 1/3 fl oz	1 qt	1 gal
1.5%	2 fl oz	1 1/2 qt	1 1/2 gal
2.0%	2 2/3 fl oz	2 qt	2 gal
3.75%	5 fl oz	3 3/4 qt	3 3/4 gal
5.0%	6 1/2 fl oz	5 qt	5 gal
10.0%	13 fl oz	10 qt	10 gal

2 tablespoons = 1 fluid ounce

Figure 3. This table is an example of a specific herbicide and the quantities of the product to mix with water to attain a desired concentration of the formulation to apply. Note the table provides the V_1 to mix in the carrier, with the quantities as either teaspoons or ounces.

The typical goal when calculating a dilution is to determine V_1, or the amount of the product to add with the carrier into the sprayer. C_1 is the original concentration, C_2 is the final concentration as recommended by the

label or a fact sheet, and V_2 is the volume in the sprayer or container. If we're making a product dilution, we start with the product at 100% (note, the a.i. will be less than 100%), and we may want a final formulation, for example, of 2% product in a 3 gallon container. Formula 2 illustrates the rearrangement of Formula 1 to solve for V_1.

Formula 2: $V_1 = \frac{C_2 V_2}{C_1}$

To obtain Formula 2, both sides of the equation in Formula 1 are divided by C_1. On the left side C_1 becomes C_1/C_1 , which equals 1, and is canceled to result in Formula 2. This rearrangement is an application of basic algebra that you may remember from high school or that a family member has recently learned.

It helps to practice the formula with some simple numbers that make sense intuitively. Let's assume the desired final formulation is 25% product with a volume of 1 gallon. We know that 1 gallon has 128 ounces. The initial or starting concentration of the product is 100% and the initial volume, the ounces of product we need to add to the mixture, is unknown. Intuitively if the final volume is 4 quarts with 25% product, we would expect one quart (1 of 4) or 32 ounces as the initial volume. Use Formula 2 to check our intuition and solve for V_1 in ounces. Remember, C_2 is 25%, V_2 is 128 ounces and C_1 is 100%.

Formula 2: $V_1 = \frac{C_2 V_2}{C_1}$

Solution 1: $V_1(ounces) = \frac{25\% \; x \; 128 \; ounces}{100\%}$

(the "%" cancels, leaving ounces on both sides of the equation)

$V_1(ounces) = 0.25 \; x \; 128$ ounces

$V_1(ounces) = 32 \; ounces$

$V_1 = 1 \; quart$

In solution 1, remember the final volume, 128 ounces, is the total volume and needs to include both the volume of the product and the carrier. You can check how you solve the equation by ensuring that the units are the same on both sides of the equation. If the units are not the same, you've made an error in the algebra.

Now, let's solve the earlier problem with initial concentration at 100%, the final concentration at 2%, and the final volume at 3 gallons in the spray tank. For starters convert gallons of spray tank to ounces.

Solution #2 is thus 7.68 ounces mixed into a total volume of 3 gallons (not 3 gallons plus 7.68 ounces). It is acceptable to round up or down to the nearest whole number, in this case round up to 8 ounces.

For solution #2, we are working with 2% of the product. We might want to know the concentration of the active ingredient. In this case, multiply the concentration of the active ingredient by the concentration of the product dilution in the formulation. Let's assume the a.i. for the product is 41% and the formulation is a 2% product dilution. Because we want to know the amount of active ingredient in the formulation, we convert the a.i. in the product to decimal notation and multiply with the product dilution of the formulation.

$\frac{128 \; ounces}{1 \; gallon} \; x \; 3 \; gallons$ = 384 ounces (note, "gallons" cancel leaving ounces, and ounces become the common measurement)

Solve for the initial volume using *Formula 2*: $V_1 = \frac{C_2 V_2}{C_1}$

Solution 2: $V_1(ounces) = \frac{2\% \; x \; 384 \; ounces}{100\%}$

(note "%" cancels from numerator and denominator)

$V_1(ounces) = 0.02 \; x \; 384$

$V_1(ounces) = 7.68 \; ounces$

Solution 3:

$$a.i.\ of\ the\ formulation = 0.41\ x\ 2\ \%$$
$$a.i.of\ the\ formulation = \ 0.82\%$$

Thus, the formulation has an active ingredient concentration of 0.82%.

Solution 3 illustrates why it is important to know if the treatment recommendation is for a product dilution or an a.i. dilution. A woodland owner may report success with a 2% product dilution in a backpack sprayer (Figure 4), but without knowing the amount of active ingredient, you don't know how to repeat the treatment. If owners are discussing the same product, then the discussion can be about product dilutions. However, if owners are discussing a treatment using Accord XRT II (50.8% a.i.) and an off-brand (e.g., 41.0%) then they need to discuss the a.i. concentration in the formulation.

For most people these calculations require some practice. It is best to practice with the mixing ratios provided on the herbicide label (Figure 3), and then you can apply the formula to new mixing ratios.

Figure 4. Backpack sprayers are inexpensive and handy tools for applying foliar, basal bark, and cut-stump applications of herbicide. Several brands of sprayers are available. Knowing the correct mixing concentration will reduce waste, minimize unnecessary applications of herbicides, and improve the success of the treatment. The sprayer brand pictured holds approximately 3 gallons, the V_2 used in Formula 2.

For additional information on woodland management go to:
www.ForestConnect.com

www.CornellForestConnect.ning.com

Layout and editorial assistance provided by Diana Bryant and Dorian Hyland.
Support for ForestConnect is provided by the Cornell University College of Agriculture and Life Sciences, Cornell Cooperative Extension, and USDA National Institute of Food and Agriculture.

03/2017