The Basics of Fertilizer Calculations for Greenhouse Crops

Joyce G. Latimer, Extension Specialist, Greenhouse Crops; Virginia Tech

Meeting the Plant's Needs

Fertilizers are designed to provide the elements necessary for plant growth. About 90% of the plant weight is made up of water. The remaining mass constitutes the plant dry weight, which is made up primarily of 17 elements that are required for plant growth. Let's define some terms.

Essential nutrients are the 17 elements required for proper plant growth and development. They are C, H, O, N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu, B, Mo, Cl, Ni.

Carbon (C), hydrogen (H), and oxygen (O) make up 90% of the plant dry weight. These elements are obtained from air or water and are not included in fertilizers.

Fertilizers contain mineral elements that supply the essential nutrients for the growth of plants.

Macronutrients are those essential nutrients that plants require in large amounts. They are N, P, and K, which are the primary macronutrients, and Ca, Mg, and S, which are the secondary macronutrients.

Micronutrients are those essential nutrients that plants require in small amounts.

Different plants may show different sensitivities to the presence or absence of these nutrients, especially the micronutrients, but they are all required for specific plant functions.

Fertilizer Analysis

Water soluble, commercial fertilizers used in the greenhouse come in a wide variety of formulations and nutrient analyses. A commercial fertilizer may contain one or all of the essential elements but the percent of each will be listed on the fertilizer label. Micronutrients may or may not be included in the formulation. If included they also will be listed in the "guaranteed analysis" section on the fertilizer bag.

Complete fertilizers:

Nitrogen (N), Phosphorous (P), Potassium (K) – complete fertilizers contain the three primary macronutrients, N, P, and K, but in a variety of proportions.

Numbers on the bag – the three numbers on the fertilizer package indicate the amounts of the three macronutrients, N, P, K, in that order, on a percent weight basis.

Example – a 20-10-20 formulation of a water soluble fertilizer contains a guaranteed analysis of 20% actual nitrogen, 10% the oxide form of phosphorus (P_2O_5) and 20% the oxide form of potassium (K_2O).

Incomplete fertilizers:

Specific nutrients – incomplete fertilizers contain less than all three of the primary macronutrients, e.g., 15-0-15 contains 15% N, no P and 15% K.

Customize the fertilizer program – incomplete fertilizers can be purchased and mixed together in the fertilizer stock tank to provide a more customized fertilizer. Generally, this tank mix will include two to eight different fertilizers. While customized mixing can be cost-effective for larger growers, it requires more skill to properly formulate and use the tank mix.

Fertilizer Injectors

Fertilizer recommendations are generally given in parts per million of nitrogen (ppm N) in the final solution being applied to the crop. Most growers use fertilizer injectors for applying fertilizers to greenhouse crops (Fig 1). These devices "inject" a specific amount of concentrated fertilizer solution (stock solution, Fig 1A) per increment of irrigation water that passes through the injector (Fig 1B). An important attribute of each fertilizer injector is the injector ratio, which is defined as volumetric ratio of stock solution to dilute fertilizer solution.

Injector ratio – the volumetric ratio of stocwk solution to dilute fertilizer solution.

Example – a 1:100 injector will deliver 100 gallons of dilute fertilizer solution for each one gallon of concentrated stock solution that is metered through the injector.
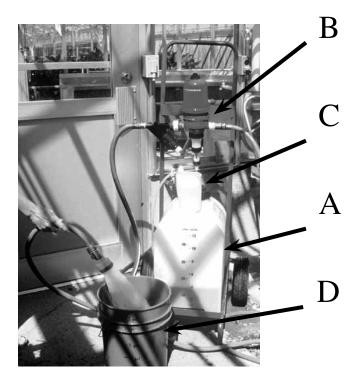

Figure 1. Fertilizer injectors draw fertilizer stock solution from the stock tank (A) and meter it out through the injector (B) at a specified ratio of stock to irrigation water when the irrigation water is flowing. This specified ratio makes up the injector ratio. Checking the calibration of a fertilizer injector involves measuring the amount of "stock" (C) taken up by the injector as a measured amount of irrigation water flows through the injector and is collected in a calibrated container (D).

A 1:200 injector will deliver 200 gallons of dilute fertilizer per gallon of stock solution. If we wanted to mix stock solutions for each of these injectors to deliver 200 ppm of nitrogen using the same fertilizer formulation, the stock solution for the 1:200 injector would have to be twice as concentrated as the one for the 1:100 injector. Thus, the injector ratio determines the concentration of the stock solution that is needed to apply a specific rate of fertilization.

Checking the Calibration of a Fertilizer Injector

Growers need to know the injector ratio in order to prepare fertilizer stock solutions. Commercial injectors range from 1:5 to 1:500, but most small growers are using 1:16, 1:100 or 1:200. Injectors should be calibrated monthly during the growing season. The injector ratios can change over time due to wear of injector parts. Most injectors do not have calibration adjustments. Therefore, it is necessary to periodically check an injector to determine its actual ratio. Adjustments to obtain a given fertilizer concentration at delivery is done by adjusting the concentration of the fertilizer stock solution. The following procedure can be used to determine the actual injector ratio.

Obtain collection container – You will need a container for collecting the water metered through the injector, i.e., the dilute solution. This container should have a capacity of 5 gallons or more, and should be calibrated in gallons. The greater the container capacity, the more accurate the determination of the injector ratio.

Obtain measuring cup – You'll also need a smaller container that is calibrated in fluid ounces. A 1-pint (16 ounce) measuring cup like those used for cooking is satisfactory. A larger measuring cup may be necessary for injectors with a 1:16 ratio.

Measure "stock" solution – Fill the measuring cup near the top with water and place the dip tube (from the fertilizer injector) into the cup (Fig. 1C). Adjust the amount of water in the cup so that the water level corresponds with the uppermost increment on the cup.

Collect "dilute" solution – Turn on the faucet and immediately begin collecting the water in the larger, calibrated collection container (Fig. 1D). Adjust the flow rate until it is approximately that which is used for irrigating plants.

Virginia Cooperative Extension

Determine amounts – Turn off the hose once you collect 5 (or more) gallons in the large container or when you nearly deplete the water from the measuring cup, whichever comes first. Determine the amount of water depleted from the measuring cup and the amount collected in the large container.

Calculate injector ratio – Use the following formula to compute the injector ratio:

Injector ratio = Gallons of water collected x 128 ounces/gallon
——————————————————————
Ounces of water depleted from measuring cup

Example 1. A grower used the procedure described above for testing a fertilizer injector. Ten gallons of water were collected in a barrel, and 13 fluid ounces were depleted from a measuring cup. What is the injector ratio for this fertilizer injector?

1. List all the variables:

a. Gallons of water collected = 10

b. Ounces of water depleted from the measuring cup = 13

2. Set up and solve the problem:

x = $\dfrac{10 \text{ gallons x } 128 \text{ oz/gal}}{13 \text{ oz}}$

= $\dfrac{1280}{13}$

= 98.46 (about 98)

3. Answer: the fertilizer injector ratio is approximately 1:98.

Checking the fertilizer EC. Another way to determine the output of your fertilizer injector is by measuring the electrical conductivity (EC) of the dilute fertilizer solution. You can draw a fertilizer sample and have it analyzed for the concentration of N by a reputable testing laboratory. Alternatively, you can get a good estimate of the fertilizer concentration by measuring the EC of the solution yourself using a portable EC meter (Fig. 2). Be sure to calibrate the EC meter prior to each use and be sure to subtract the EC of your clear water from the fertilizer reading. Compare the corrected value for the EC of your fertilizer solution to that listed on the fertilizer bag

for the ppm N you intended to be applying (Fig. 3). During the crop cycle, especially for short-term crops like bedding plants, you should measure the EC of your fertilizer solution on a weekly basis to check that the injector is working properly.

GENERAL PURPOSE 20-10-20
(For Continuous Liquid Feed Programs)

DILUTION RATIO	PER GALLON OF CONCENTRATE		
	50 PPM NITROGEN (EC=.33)	100 PPM NITROGEN (EC = .65)	200 PPM NITROGEN (EC = 1.30)
1:15 (HOZON)	.5 Ounces	1.0 Ounces	2.0 Ounces
1:100 INJECTOR	3.38 Ounces	6.75 Ounces	13.5 Ounces
1:200 INJECTOR	6.75 Ounces	13.5 Ounces	27.0 Ounces

TO CONVERT OUNCES/GALLON TO GRAMS/LITER, MULTIPLY BY 7.5
DISSOLVES QUICKLY IN HOT WATER, LIMIT OF SOLUBILITY 4.0 LBS./GALLON
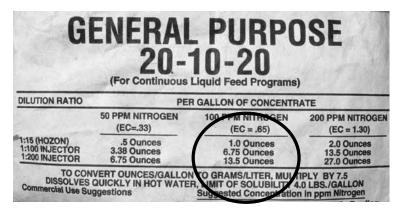Commercial Use Suggestions   Suggested Concentration in ppm Nitrogen

Figure 3. The fertilizer label presents the EC of several concentrations of the diluted fertilizer. Circled is the EC of 100 ppm N, EC=.65. For weekly checks of injector accuracy, measure the EC of the dilute fertilizer solution and subtract the EC of your clear water and compare it to the EC given on the bag.

Fertilizer Stock Solution Calculations

Growers must accurately determine the amount of fertilizer needed to mix stock solutions of fertilizers. Most of the manufacturers of commercial fertilizers and fertilizer injectors have produced tables that simplify this task. Information is also provided on

Figure 2. Portable electrical conductivity (EC) meters can be used to measure the EC of the dilute fertilizer solution to verify that the injector is working within the expected range. Compare the EC of the solution to that recommended on the fertilizer bag (Fig. 3) or the fertilizer label.

Virginia Cooperative Extension

—————————————————— www.ext.vt.edu

fertilizer bags (Fig. 3). Without recourse to tables or bags, growers can use formulas to calculate the amount of fertilizer needed. If you know the rate of fertilization (in ppm N) that you want to apply to the crop, the percentage of the nitrogen in the fertilizer, and the injector ratio, then calculations are simplified by the following formula:

Amount of fertilizer to make 1 volume of stock solution

$$= \frac{\text{Desired conc in ppm} \times \text{Dilution factor}}{\text{\% of element in fertilizer} \times C}$$

where the dilution factor is the larger number of the fertilizer injector ratio and the conversion constant (C) is determined by the units in which you want to measure the fertilizer:

Unit	Conversion constant (C)
Ounces per U.S. gallon	75
Pounds per U.S. gallon	1200
Grams per liter	10

This formula allows you to easily calculate the amount of fertilizer needed to mix stock solutions. Generally, the calculations are based on the percentage of nitrogen, but using this formula, you can make up solutions for any given element. This formula can be used with any fertilizer injector and any unit of measurement. Most growers in the United States prefer ounces (or pounds) of fertilizer per U.S. gallon. A conversion constant is also given for those who use the metric system.

Example 2. You have a 1:98 fertilizer injector and a fertilizer with an analysis of 20-10-20 (%N-%P$_2$O$_5$-%K$_2$O). You want to apply a 200 ppm solution of nitrogen at each watering. How many ounces of fertilizer would you have to weigh out to fill a 20-gallon stock tank with concentrate?

1. List all the variables:

a. Desired concentration in ppm = 200

b. Injector ratio = 1:98; dilution factor = 98

c. Fertilizer analysis = 20-10-20 = 20% N

d. Conversion constant: want to know number of ounces of fertilizer to make 20 gallons of concentrate = Use 75 as C

2. Set up and solve the problem:

x oz Fertilizer / gal

$$= \frac{200 \text{ ppm N} \times 98}{20\% \text{ N} \times 75}$$

$$= \frac{19600}{1500}$$

$$= 13.1 \text{ oz } 20\text{-}10\text{-}20 \text{ /gal}$$

x oz Fertilizer / stock tank

$$= 13.1 \text{ oz/gal} \times 20 \text{ gal}$$

$$= 262 \text{ oz}$$

Or, divide by 16 oz/lb = 16 lb 6 oz of 20-10-20 for 20 gal of stock solution

3. Answer: add 16 lb 6 oz of 20-10-20 to the stock solution bucket and fill to the 20 gallon mark.

Example 3. By the 25-lb bag. Many growers do not have access to an accurate scale for weighing fertilizers. Since most commercially formulated N-P-K fertilizers are packaged in 25-pound bags, we can easily determine how many gallons of stock solution to mix up from one bag of fertilizer to apply 200 ppm N using a 1:98 injector:

1. Convert 25 pounds into the equivalent amount of ounces:

   25 lbs/bag x 16 oz/lb = 400 oz/bag

2. Using the information in Example 2, we then divide 400 oz/bag by 13.1 oz/gal to get the number of gallons of stock we can prepare from a single bag of fertilizer:

   400 oz/bag ÷ 13.1 oz/gallon = 30.5 gal/ bag

3. Thus, one 25-pound bag of 20-10-20 fertilizer will make about 30 gallons of stock for a 200 ppm N solution when using a 1:98 injector.

It is important to remember that the final volume of stock solution should be 30 gal. This means we add the fertilizer first, and then add water (warm water works best) for a final volume of 30 gallons. Adding the bag of fertilizer to 30 gallons of water will give us more than 30 gallons of stock and thus a more dilute stock solution than desired. Of course, you must make sure that you have a storage tank (barrel or trash can)

Virginia Cooperative Extension

large enough to accommodate your stock solution. Be sure to keep the stock solution dark to prevent nutrient degradation. Always verify that the fertilizer you are preparing has sufficient solubility to dissolve in the amount of water you intend to use for your stock solution volume. Maximum solubility is listed on the bag. For most soluble fertilizers, it ranges from about 2.5 to 4 lbs per gallon of water.

Incomplete Fertilizer or Tank Mix Calculations

We can also use these calculations to determine the content of other fertilizer components in our fertilizer solution or we can develop a fertilizer solution based on an element other than nitrogen. This is important when using incomplete fertilizers to develop your own tank mixes or to supplement a complete fertilizer. When calculating ppm of P or K we must account for the oxide form of the elements in the fertilizer. We can use the simple rhyming rule "%K and %P equals 1.2 and 2.3" to convert from the oxide to the elemental forms for phosphorus and potassium, that is, from $\%P_2O_5$ to %P and from $\%K_2O$ to %K.

Example 4. You have a fertilizer with an analysis of 20-10-20. What is the percentage of phosphorus and potassium in the elemental form?

1. **List all the variables to find out what is known and unknown:**

   a. Fertilizer analysis = 20-10-20 = 10% P_2O_5 and 20% K_2O

   b. **Conversion rule: "%K and %P equals 1.2 and 2.3."**

2. **Set up the problem:**

$$\%P = \frac{\% P_2O_5}{2.3}$$

$$= \frac{10}{2.3}$$

$$= 4.3\% \text{ P in 20-10-20}$$

$$\%K = \frac{\% K_2O}{1.2}$$

$$= \frac{20}{1.2}$$

$$= 16.7\% \text{ K in 20-10-20}$$

3. **Answer:** 20-10-20 contains 4.3% elemental phosphorus and 16.7% elemental potassium.

The conversion rule is useful when we desire to fertilize with simple fertilizers such as potassium nitrate (13-0-44). When plants are grown in media which contain adequate levels of phosphorus (for example, from a pre-plant addition of superphosphate), it is often recommended that 200 ppm of N and K be applied at each watering. We can achieve this fertilization program using potassium nitrate and calcium nitrate (15.5-0-0). We can use the formula previously given to calculate ppm K if we first convert from the oxide to the elemental form.

Example 5. You have a 1:100 injector and want to use potassium nitrate (13-0-44) and calcium nitrate (15.5-0-0) to supply 200 ppm of N and K with each watering. How many ounces of each fertilizer would you have to weigh out to make 1 gallon of concentrate?

1. **List all the variables** to find out what is known and unknown:

   a. Desired concentration in ppm = 200 N and K

   b. Injector ratio = 1:100; dilution factor = 100

   c. Fertilizer analyses = 13-0-44 and 15.5-0-0

   d. Conversion constant: want to know number of ounces of each fertilizer to make one gallon of concentrate = Use 75 as C

2. First, convert % K_2O to % K for potassium nitrate:

$$\%K = \frac{\% K_2O}{1.2}$$

$$= \frac{44}{1.2}$$

$$= 36.7\% \text{ K in 13-0-44}$$

3. Potassium nitrate supplies both potassium and nitrogen, whereas calcium nitrate supplies only nitrogen. Therefore, **figure out how much potassium nitrate is needed** to supply 200 ppm K:

$$x = \frac{200 \text{ ppm K x 100}}{36.7\% \text{ K x 75}}$$

$$= \frac{20000}{2752.5}$$

$$= 7.27 \text{ oz 13-0-44 /gal}$$

4. Next, **figure out the ppm N supplied** by the amount of potassium nitrate determined in step 3. Potassium nitrate supplies 36.7% elemental potassium and 13% elemental nitrogen. The ratio of elemental potassium to elemental nitrogen remains the same, regardless of whether the fertilizer is in solid form or dissolved in water. This relationship also holds true for other fertilizer salts. Therefore:

$$\text{x ppm N} = 13\% \text{ N}$$

$$\frac{\text{x ppm N}}{200 \text{ ppm K}} = \frac{13\% \text{ N}}{36.7\% \text{ K}}$$

$$36.7 \text{ x} = 2600$$

$$\text{x} = \frac{2600}{36.7}$$

$$= 70.8$$

$$= \text{about 71 ppm N supplied by potassium nitrate}$$

5. Since we desire 200 ppm N and potassium nitrate supplies only 71 ppm N, we must make up the rest of the nitrogen with calcium nitrate. Therefore:

$$200 \text{ ppm N} - 71 \text{ ppm N} = 129 \text{ ppm N needed from calcium nitrate}$$

6. Lastly, **determine the amount of calcium nitrate needed** to supply 129 ppm N:

$$\text{x} = \frac{129 \text{ ppm N x } 100}{15.5\% \text{ N x } 75}$$

$$= \frac{12,900}{1162.5}$$

$$= 11.1 \text{ oz } 15.5\text{-}0\text{-}0 \text{ /gal}$$

7. **Answer:** add 7.3 ounces of potassium nitrate and 11.1 ounces of calcium nitrate to a stock solution bucket and fill to the 1 gallon mark. This will supply 200 ppm of N and K with each watering when using a 1:100 injector.

Conclusion

With the aid of a hand-held calculator, you can easily determine the proper amount of fertilizer for making stock solutions. Remember, always recheck your calculations to ensure they are correct: errors may be very costly! Better yet, have someone else check your calculations. Keep records of your calculations for future reference. Check the EC of the final fertilizer solution against that given on the bag or fertilizer label to verify that your calculations were correct (remember to subtract the EC of your clear water) and monitor the EC of your diluted fertilizer solution on a weekly basis during the crop cycle. Check the calibration of your injector on a monthly basis during crop production or whenever you suspect a problem.

Other Resources for Information on Greenhouse Fertilization:

A Water Quality Toolkit for Greenhouse and Nursery Production (PennState)
https://extension.psu.edu/a-water-quality-toolkit-for-greenhouse-and-nursery-production

Growing Media for Container Production in a Greenhouse or Nursery Part II – Physical and Chemical Properties (Univ Arkansas)
https://www.uaex.edu/publications/pdf/FSA-6098.pdf

Basic Fertilizer Programs for Containerized Greenhouse Crops
https://ag.umass.edu/greenhouse-floriculture/fact-sheets/basic-fertilizer-programs-for-containerized-greenhouse-crops

Adapted from "Fertilizer Calculations for Greenhouse Crops," Thomas H. Boyle, University of Massachusetts Extension Service.