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Understanding Plant Nutrition

Fertilizers And Macronutrients

Argo and Fisher take a microscope to the details that can help growers make informed decisions on nutrients.

by ***BILL ARGO AND PAUL FISHER***

WHEN you select a water-soluble fertilizer, the primary goal should be to supply plants with a sufficient amount of essential plant nutrients for good growth and flowering. In this article, we will focus on macronutrients (nitrogen, phosphorus, potassium, calcium, magnesium and sulfur) supplied by water-soluble fertilizers. We will discuss macronutrient sources, fertilizer formulations and the application of fertilizer to the crop. In subsequent articles, we will discuss other aspects of fertilization including micronutrients sources and formulations and controlled-release fertilizer.

Table 1. Formulation of selected commercially available, blended water-soluble fertilizers

N-P_2O_5-K_2O Formula	Percent NH_4-N + Urea	Concentration of other nutrients (in ppm) at a fertilizer concentration of 200 ppm N				Fertilizer salts[1]
		P	K	Ca	Mg	
21-7-7	100%	28	55	0	1	Potassium chloride, MAP, ammonium sulfate, urea, magnesium sulfate
25-10-10	89%	34	66	0	1	Potassium nitrate, MAP, urea, magnesium sulfate
9-45-15	100%	430	276	0	1	MAP, potassium chloride, magnesium sulfate
20-20-20	69%	86	166	0	1	MAP, potassium nitrate, urea, magnesium sulfate
20-10-20	40%	43	166	0	1	Ammonium nitrate, MAP, potassium nitrate, magnesium sulfate
15-15-15	52%	86	166	0	1	MAP, potassium nitrate, sodium nitrate, urea, magesium sulfate
20-0-20-6 Ca	25%	0	166	60	0	Ammonium nitrate, calcium nitrate, potassium nitrate
17-5-17-3 Ca-1 Mg	25%	25	166	35	11	Ammonium nitrate, calcium nitrate, magnesium nitrate, MAP, potassium nitrate
15-3-20-3 Ca-1 Mg	16%	17	221	40	13	Ammonium nitrate, calcium nitrate, magnesium nitrate, MAP, potassium nitrate
14-4-14-5 Ca-2 Mg	14%	24	166	71	28	Ammonium nitrate, calcium nitrate, magnesium nitrate, MAP, potassium nitrate
13-2-13-6 Ca-3 Mg	5%	13	166	92	46	Calcium nitrate, magnesium nitrate, MAP, potassium nitrate
14-0-14-6 Ca-3 Mg	8%	0	166	85	42	Calcium nitrate, magnesium nitrate, potassium nitrate
15-0-15-11 Ca	13%	0	166	146	0	Ammonium nitrate, calcium nitrate, potassium nitrate
34-0-0	50%					Ammonium nitrate
12-62-0	100%	444				Ammonium phosphate or MAP
15.5-0-0-19 Ca	10%			245		Calcium nitrate
11-0-0-9 Mg	0%				163	Magnesium nitrate
13-0-46	0%		587			Potassium nitrate
46-0-0	100%					Urea

[1] Chemical formulas for the individual fertilizer salts are: Ammonium nitrate (NH_4HO_3), ammonium sulfate ($(NH_4)_2SO_4$), calcium nitrate ($5Ca(NO_3)_2{\cdot}NH_4NO_3$ ($10H_2O$)), magnesium nitrate ($Mg(NO_3)_2$ ($6H_2O$)), magnesium sulfate ($MgSO_4$ ($7H_2O$)), monoammonium phosphate ($NH_4H_2PO_4$), potassium chloride (KCl), potassium nitrate (KNO_3), Sodium nitrate (NaNO3), urea ((NH2)2CO).

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Fertilizer Formulations

Water-soluble fertilizers come in two types, either individual fertilizer salts or blended fertilizers. Fertilizer salts are chemicals containing nutrients that can dissolve into a water-soluble form that are needed for plant uptake. For example, potassium nitrate (KNO_3) will dissolve into separate potassium ions and nitrate ions. Blended fertilizers are combinations of two or more fertilizer salts that supply several macronutrients. For example, 13-2-13 is a blend of calcium nitrate, magnesium nitrate, monoammonium phosphate and potassium nitrate, and so supplies nitrogen, phosphorus, potassium, calcium and magnesium.

When formulating blended fertilizers, there are eight water-soluble sources of nitrogen commonly used (Table 1), some of which only supply nitrogen, like urea and ammonium nitrate. However, for most other nutrients, the choices are limited. For example, calcium nitrate is the only form of water-soluble calcium. There is also typically only one source of potassium, potassium nitrate. Monoammonium phosphate (MAP) is the usual source of phosphorus. Magnesium is supplied by either magnesium sulfate or magnesium nitrate. Sulfur is supplied by ammonium sulfate or magnesium sulfate.

Because of limitations in the number of salts used to blend fertilizers, the ratio of macronutrients and their compatibility when mixed directly affects the formulation of the fertilizer, for example:

- Fertilizers that are high in phosphorus also tend to be high in ammoniacal nitrogen, because phosphorus is usually supplied as monoammonium phosphate.
- Fertilizers that contain calcium are also high in nitrate, because calcium nitrate is the only water-soluble source of calcium. In fact, all the commercially available fertilizer that contains calcium also has ammoniacal nitrogen levels of 25 percent or less of the total nitrogen.
- Calcium nitrate and monoammonium phosphate or monopotassium phosphate cannot be mixed in the same concentrated stock solution at high concentrations because insoluble calcium phosphate will form. However, the amount of calcium and phosphorus that can be mixed in the same stock tank can be increased by lowering the pH of the stock tank solution. Commercially available fertilizers that contain calcium and phosphorus tend to have low levels of phosphorus (i.e. 13-2-13-6 Ca-3 Mg) and will also contain a weak acid to lower the pH of the concentrated stock solution.
- Since calcium nitrate and magnesium sulfate are incompatible in the same stock tank, a fertilizer that contains calcium will use magnesium nitrate as the magnesium source. A fertilizer that contains magnesium without calcium will use magnesium sulfate as the magnesium source.

Nutrient Concentrations

Most fertilizer recommendations are given based on a concentration of nitrogen applied to a crop. In North America, that concentration is usually given in parts-per-million or ppm. One ppm is equivalent to 1 mg per liter. In other words, one liter (about 33 fluid ounces) of fertilizer solution with

a concentration of 100 ppm N will contain 100 mg of nitrogen. Sometimes, concentrations are given in mMol of nitrogen. One mMol of nitrogen is equal to 14 ppm N.

In many cases, the concentration of the other macronutrients are either not known or are ignored. To calculate the concentration of calcium, magnesium or sulfur supplied by a blended fertilizer, you need to know the concentration of nitrogen in the fertilizer solution and the ratio of nitrogen to calcium, magnesium or sulfur that is listed under the "guaranteed analysis" on any fertilizer bag. For example, to calculate the concentration of calcium supplied by 13-2-13 (6 percent Ca) at 200 ppm N, you divide the percent of Ca by the percent of N, then multiply by the nitrogen concentration of the fertilizer solution.

So at 100 ppm N, you are also supplying about 92 ppm Ca.

[illegible]				
13 (% N)	x	200 (N conc.)	=	92

An extra step is required to calculate the concentration of phosphorus or potassium. A fertilizer formula reports phosphorus as P_2O5, not actual phosphorus (P), and potassium is reported as K_2O, not actual potassium (K). To convert P_2O5 to P, multiply the P_2O_5 value by 0.43, and to convert K_2O to actual K, multiply the K_2O value by 0.83. For example, using the equation above, the P_2O_5 and K_2O values supplied by 13-2-13 at 200 ppm N would be 30 ppm and 200 ppm. This converts to an actual P concentration of 13 ppm P, and an actual K concentration of 166 ppm K.

Applying Fertilizers

Water-soluble fertilizers are typically applied using fertilizer injectors or proportioner. These devices add a concentrated fertilizer solution to the irrigation water at some ratio. For example, a 1:100 injector will add 1 gallon of concentrated fertilizer to 100 gallons of water. If the desired solution concentration coming out of the end of the hose is 100 ppm N, then the concentrated stock solution that the fertilizer injector is adding to the irrigation water has to have a concentration of 10,000 ppm N (or 100 times that of the desired diluted concentration)

Table 2. Calculating the amount of fertilizer needed for a stock solution.

Step #1	Multiply the desired nitrogen concentration (in ppm N) by the stock tank volume and the injector ratio.
Step #2	Multiply the percent nitrogen in the formula by 75.
Step #3	Divide the value from Step #1 by the value from Step #2.
[illegible]	
Step #1	100 x 1 x 100 = 10,000
Step #2	13 x 75= 975
Step #3	10,000 ÷ 975 = 10.3
[illegible]	

The amount of fertilizer needed to make a concentrated stock solution is often listed on the fertilizer bag. If the information is not contained on the fertilizer bag, then calculate it using the formula given in Table 2.

Be careful about adding too much fertilizer to the stock tank or it may not all be soluble. The solubility of potassium nitrate, in particular, is greatly affected by water temperature. The lower the water temperature of the stock tank, the lower the solubility of any fertilizer made with potassium nitrate. If you are using well water (with a temperature of about 55°F) to dissolve the fertilizer or the ambient temperature in the greenhouse (and stock tank) is 60°F or lower, then it may not be possible to dissolve more than 2 to 3 pounds (48 to 64 ounces) per gallon of stock.

Another way to determine the concentration of fertilizer you are applying is to use the electrical conductivity

Table 3. Relationships between EC and nitrogen concentration for several common blended fertilizer and fertilizer salts. There can be some slight differences between the values of the same formulation from different companies. You should always obtain a fertilizer chart from your manufacturer.

N-P_2O_5-K_2O Formula	EC chart (solution EC vs. ppm N)					
	50	100	150	200	300	400
21-7-7	0.28	0.56	0.84	1.12	1.68	2.23
9-45-15	0.60	1.20	1.80	2.41	3.60	4.82
20-20-20	0.20	0.40	0.60	0.80	1.20	1.60
20-10-20	0.33	0.66	0.99	1.32	1.98	2.63
21-5-20	0.29	0.58	0.93	1.16	1.86	2.33
17-5-17	0.32	0.64	0.96	1.28	1.92	2.56
13-2-13	0.34	0.68	1.02	1.36	2.04	2.72
14-0-14	0.34	0.68	1.02	1.36	2.04	2.72
15-0-15	0.37	0.74	1.11	1.48	2.22	2.96
Ammonium nitrate	0.24	0.48	0.72	0.96	1.44	1.92
Ammonium phosphate	0.36	0.71	1.08	1.42	2.14	2.84
Calcium nitrate	0.31	0.63	0.94	1.26	1.88	2.51
Magnesium nitrate	0.55	1.09	1.64	2.18	3.28	4.36
Potassium nitrate	0.27	0.56	0.83	1.11	1.66	2.23

(EC) of the fertilizer solution. For all fertilizers, there is a relationship between the concentration of nutrients and EC (Table 3). In most cases, the relationship is given between the concentration of nitrogen and the EC.

To determine the nitrogen concentration coming from the hose, two EC measurements must be taken: EC of the fertilizer solution and EC of the irrigation water (with no fertilizer). Because the values given in the EC chart are for the fertilizer mixed in pure water, the irrigation water EC must be subtracted from the fertilizer solution EC, for example, 20-10-20 with a solution EC of 1.2 and an irrigation water EC of 0.5. Subtract the solution EC (1.2) from the irrigation water EC (0.5) to get 0.7, which corresponds to a fertilizer concentration of about 100 ppm N.

Calculate ppm N from a 20-10-20 fertilizer solution with a total EC of 1.8 mS and an using irrigation water with an EC of 0.5 mS.

Using EC values to determine fertilizer concentrations has some limitations. EC values are generic measurements because they measure the conductivity of all the salts in the solution, not just the fertilizer. It is important to remember that the relationship between EC and nitrogen concentration is unique to that specific fertilizer salt or blend of salts in pure water. Never assume that all fertilizers have the same relationship between EC and ppm N.

Understanding how to fertilize your crop requires more than just selecting a fertilizer formulation off the shelf. You need to know what other nutrients are in the fertilizer, the relationship between the concentration of nitrogen and the other macronutrients, and how to supply them to the crop at a desired concentration. In next month's article, we will discuss micronutrients. **GG**

EC of [illegible]	-	EC of water	=	EC of fertilizer solution
1.8 mS	-	0.5 mS	=	1.3 mS

From the chart above, 20-10-20 with an EC of 1.3 mS would give a concentration of about 200 ppm N.
To predict the EC of 20-10-20 at 200 ppm N using an irrigation water with an EC of 0.5 mS.

EC of 20-10-20 at 200 ppm N	+	EC of water	=	EC of fertilizer solution
1.3 mS	+	0.5 mS	=	1.8 mS

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