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Understanding Plant Nutrition: Fertilizers And Micronutrients

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

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MICRONUTRIENT (iron, manganese, zinc, copper, boron and molybdenum) nutrition is different from managing macronutrients, such as nitrogen, in three fundamental ways. First, the solubility and plant availability of micronutrients is affected by media pH to a much greater extent than is macronutrient solubility. Second, the difference between acceptable concentrations of micronutrients and concentrations that are either too low (deficiencies) or too high (toxicities) is small compared to a broader range for macronutrients. Finally, while most macronutrients are mobile within the plant, most micronutrients are immobile, and so a constant supply is needed for the duration of the crop or growth and plant appearance may be affected. In this article, we will focus on micronutrient sources, and how they are applied to a crop.

Fig. 1. Petunia (A and B) and calibrachoa (C and D) showing iron deficiency at a high pH (7.0).

Table 1. Common sources of micronutrients used for incorporation into root media at mixing.

Common Name	Formula	Fe	Mn	Zn	Cu	B	Mo	S
Iron sulfate heptahydrate, Ferrous sulfate heptahydrate	FeSO4·7H2O	20.5%						11%
Iron sulfate monohydrate, Ferrous sulfate monohydrate	FeSO4·H2O	31.0%						17%
Iron Oxide, Ferric Oxide	Fe2O3	62.0%						
Manganese sulfate	MnSO4·H2O		24.6%					12%
Manganese oxide	MnO		77.4%					
Zinc sulfate	ZnSO4·7H2O			36.4%				15%
Zinc oxide	ZnO			80.3%				
Copper sulfate	CuSO4·5H2O				25.0%			14%
Copper oxide	CuO				79.8%			
Boric acid	H3BO3					17.5%		
Borax	Na2B4O7·10H2O					11.3%		
Solubor	Na2B8O13·4H2O					20.5%		
Sodium molybdate	Na2MoO4·2H2O						39.7%	
Ammonium molybdate	(NH4)6Mo7O24·4H2O						54.3%	
FTE 555 (Frit Industries)		14.0%	5.0%	5.0%	1.5%	0.80%	0.070%	0%
MicroMax (Scotts)	sulfates	12.0%	2.5%	1.0%	0.5%	0.10%	0.050%	15%

Note: Several fertilizer companies also sell starter fertilizer blends that contain both macronutrients and micronutrients.

Preplant Sources

In soilless media, preplant sources of micronutrients are often added at mixing. In general, the sources in starter fertilizers can include both soluble forms (sulfates) and insoluble forms (oxides or fritted trace elements) (Table 1). Sometimes, water-soluble fertilizers

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or micronutrient sources are sprayed onto the media at mixing (Table 2). In general, micronutrients are incorporated in a root medium at low rates and therefore only represent a relatively small percentage of the total amount applied to a crop.

The one exception is often iron. Iron sulfate at rates up to 4 pounds per cubic yard (2.4 kg/m3) is sometimes added in a starter fertilizer to supply iron and to help keep the medium-pH low when using irrigation water that contains high concentrations of alkalinity. Depending on the rate used, the effect will probably not last for more than three to four weeks and may need to be reapplied.

There are several considerations for using iron sulfate for iron nutrition and acidification in a starter fertilizer. Iron sulfate oxidizes easily, and so it can be difficult to obtain consistent results. Never mix iron sulfate with limestone before incorporation, because the high pH of the lime can cause the iron sulfate to oxidize and become ineffective. Finally, if you are using both iron sulfate and lime in a mix, you may get better, more uniform pH control by leaving the iron sulfate out completely and reducing the lime incorporation rate.

Table 2. Common water-soluble sources of micronutrients

Common Name	Formula	Fe	Mn	Zn	Cu	B	Mo	S
Iron sulfate, Ferrous sulfate	FeSO4·7H2O	20.1%						14%
Sequestrene Fe, Dissolzine E-FE-13	FeEDTA	13.0%						
Sequestrene 330, Sprint 330, Dissolzine D-FE-11	FeDTPA	10.0%						
Sequestrene 138, Sprint 138, Dissolzine Q-FE-6	FeEDDHA	6.0%						
Manganese sulfate	MnSO4·H2O		24.6%					12%
Manganese chelate	MnEDTA		13.0%					
Zinc sulfate	ZnSO4·7H2O			36.4%				15%
Zinc chelate	ZnEDTA			15.0%				
Copper sulfate	CuSO4·5H2O				25.0%			14%
Copper chelate	CuEDTA				14.0%			
Boric acid	H3BO3					17.5%		
Borax	Na2B4O7·10H2O					11.3%		
Solubor	Na2B8O13·4H2O					20.5%		
Sodium molybdate	Na2MoO4·2H2O						39.7%	
Ammonium molybdate	(NH4)6Mo7O24·4H2O						54.3%	
Blended Micronutrient formulas								
Chelated Micronutrient Mix (Plant Products)	EDTA Chelates	7.0%	2.0%	0.4%	0.1%	1.3%	0.06%	0%
Chelated Trace Element Mix (Jack's Professional)	EDTA Chelates	1.5%	0.7%	0.07%	0.1%	0.2%	0.02%	0%
Chelated Water-soluble micros (GreenCare)	EDTA Chelates	5.0%	2.5%	2.5%	1.2%	1.2%	0.50%	0%
Chemec (Plant Marvel)	EDTA Chelates	1.2%	0.6%	0.6%	0.6%	0.2%	0.01%	0%
Compound 111 (Scotts)	EDTA Chelates	1.5%	0.1%	0.1%	0.1%	0.2%	0.02%	0%
Formula 222 (Masterblend)	EDTA Chelates	3.0%	0.2%	0.1%	0.2%	0.4%	0.04%	0%
Mix of Soluble Traces (Jack's Professional)	Sulfates	9.0%	9.0%	4.4%	2.3%	1.4%	0.04%	15%
Sol-Trace (Plant Marvel)	Sulfates	7.5%	8.0%	4.5%	3.2%	1.4%	0.04%	14%
Stem (Scotts)	Sulfates	7.5%	8.0%	4.5%	3.2%	1.3%	0.04%	14%
Water-soluble Micros (GreenCare)	Sulfates	7.0%	3.5%	3.5%	1.7%	1.7%	0.70%	14%
Water-soluble Micros (Masterblend)	Sulfates	7.5%	8.0%	4.5%	3.2%	1.5%	0.05%	14%

Fig. 2. Seed geranium (A, B and C) and marigold (D) showing iron-manganese toxicity at a low pH (5.0).

Water-Soluble Sources

In soilless media culture, most micronutrients are applied to a crop after planting. The sources can include individual micronutrient sources blended together, commercially prepared micronutrient blends or the micronutrient package contained in a commercially prepared water-soluble fertilizer (Table 2).

The sources of water-soluble micronutrients come in two forms, inorganic salts (all micronutrients) or chelates (only iron, manganese, zinc and copper). Inorganic salts are materials that dissolve in water to form ions that are available to the plant. For example, iron sulfate will dissolve into separate iron (Fe) and sulfate (SO4) ions.

Chelates are organic molecules that envelop the ion and protect it from interacting with other ions in the soil solution. There are many chelating molecules available, but only three that are commonly used in horticulture: EDTA, DTPA and EDDHA. These abbreviations refer to the chemical structure of the organic molecule. In general, manganese, zinc and copper chelates are only found in the EDTA form. In comparison, there are three forms of iron chelate, FeEDTA, FeDTPA and FeEDDHA, although the most common form is FeEDTA.

With iron nutrition, the form of iron is very important. The three common chelated forms (iron-EDDHA, DTPA and EDTA) differ in their ability to hold onto the iron (and therefore keep iron soluble and available to plants) as the media pH increases. Between a media pH of 4.0 to 5.5, any form of iron will work (including iron sulfate) at supplying iron to the plant. However, as the media pH increases above 7.0, only the iron from Iron-EDDHA has high solubility. Research has shown that the ranking of iron forms from most effective to least effective at supplying iron at high media pH is Iron-EDDHA > Iron-DTPA > Iron-EDTA > Iron sulfate. If iron is applied in a form that is not soluble because of high media pH, then most of the nutrient will not be available to plants until media pH is lowered.

Table 3. Approximate concentration of micronutrients supplied by either "General Purpose" formulas or "peat-lite" formulas at a nitrogen concentration of 200 ppm N. Micronutrient concentration given in ppm or mg/L.

	Fe	Mn	Zn	Cu	B	Mo
General Purpose	0.5	0.1	0.1	0.05	0.05	0.03
Peat lite	1.0	0.4	0.4	0.3	0.2	0.08

Commercially prepared water-soluble fertilizers usually contain micronutrients, with iron most commonly supplied as iron-EDTA. Manganese, zinc and copper will be supplied in the EDTA form for most N-P-K fertilizers (example are 20-10-20, 20-20-20 and 21-7-7), while sulfates are often used in formulas that contain calcium and magnesium (example is 13-2-13 or 15-5-15). Since the amount of sulfate supplied by the inorganic salts is very low compared with the calcium, there is no problem with precipitation between the sulfate and the calcium. In all formulas, boron and molybdenum are supplied as inorganic salts.

Applying Micronutrients

Commercially prepared water-soluble fertilizers contain micronutrients at one of two levels (Table 3). "General Purpose" formulas were designed when field soil was a primary component in container media. Because field soil often contained micronutrients, the levels contained in these fertilizer formulas were relatively low. Peat-lite formulas were designed for soilless media culture, and therefore have higher micronutrient levels (Table 3).

To calculate the concentration of micronutrients supplied by a blended fertilizer, you need to know the concentration of nitrogen in the fertilizer solution and the ratio of nitrogen to that micronutrient that is listed under the "Guaranteed analysis" on any fertilizer bag. For example, to calculate the concentration of iron supplied by a 20-10-20 peat-lite formula (0.1 percent Fe) at 200 ppm N, you divide the percent of Fe by the percent of N, then multiply by the nitrogen concentration of the fertilizer solution.

So at 200 ppm N, you are also supplying about 1 ppm Fe. If this 20-10-20 were a "General Purpose" formula, then percentage of Fe would be about 0.05 percent and the concentration of iron supplied by the fertilizer at 200 ppm N would be about 0.5 ppm Fe.

For growers who are adding micronutrients to the fertilizer, a "safe" concentration would be something similar to that supplied by a peat-lite water-soluble fertilizer at a concentration of 100 and 200 ppm N. Using iron as an example, that would correspond to a concentration of 0.5 to 1.0 ppm Fe from one of the water-soluble sources found in Table 2. If you are adding additional micronutrients to a water-soluble fertilizer, remember to take the micronutrients supplied by the water-soluble fertilizer into your calculation.

$$\frac{0.1\ (\%\mathrm{Fe})}{20\ (\%\ \mathrm{N})} \times 200\ (\mathrm{N\ conc.}) = 1$$

Acceptable pH Ranges For Crops

When an acceptable pH range of a crop is recommended, it is usually based on the use of a peat-lite fertilizer formulation applied at a moderate concentration of 100 to 200 ppm N. The micronutrient (and especially iron) form and concentration in that fertilizer greatly influences this acceptable pH range.

Take an iron-inefficient crop like petunias as an example. The acceptable pH range for petunias is often listed at 5.5 to 6.2. However, the acceptable pH range could be more narrow (and lower) if a "General Purpose" fertilizer formula (lower iron concentration) or a sulfate-based micronutrient formula (iron solubility issues) were used to ensure that enough iron is supplied. Alternatively, the acceptable pH range could be broader if the concentration of applied micronutrients was increased, or if the iron source was changed from FeEDTA to FeDTPA or FeEDDHA.

However, just increasing micronutrient concentrations and neglecting pH management also has risks. While that strategy may work for a single crop such as petunia, it can cause problems with other crops in your greenhouse. For example, higher iron concentrations increase the risk of iron toxicity in iron-efficient crops such as geraniums or marigolds. In next month's article, we will discuss controlled-release fertilizers. **GG**

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