GREENHOUSE NUTRITION

Jonathan M. Frantz USDA-ARS, 2801 W Bancroft, Mail Stop 604, Toledo, OH 43606
jonathan.frantz@utoledo.edu

To develop a good fertilization program, we must first consider many other features including species, greenhouse type, irrigation method, media type, goals, disease pressure, environment, market, container type, production time, water quality, water consistency, and desire for fertilization control, to name a few. There is obviously no way one can discuss all of these in a brief seminar, much less an intensive, one semester collegiate course, so I will need to assume a few things prior to discussing greenhouse nutrition. First, a few words on media and water.

GROWTH MEDIA

More and more of the industry is moving away from soil in the media and into either hydroponics or soilless (peat-based) media. I once visited a grower who quipped that "soilless media is great…if there's the right amount of soil in it." There are many benefits provided by soil that have not been met with soilless media products yet, but since the vast majority is not using soil, I will not discuss it here. Peat has tremendous aeration capacity and good water holding capacity, is relatively inexpensive and may not need to be pasteurized prior to use. Some growers have tried to boost peat's water holding capacity by the addition of polymers of various type with mixed results. For the ultimate in potential control and lessening environmental impact, hydroponics is the method of choice for many growers. All choices have benefits and drawbacks, but the choice in media has great influence on how to fertilize.

WATER

What is your water source, how consistent is the water, and what is the water quality? If you haven't done so, get your water tested for elemental content, pH, EC, and alkalinity, and get it tested regularly. This is the backbone of your fertilizer management and without this information, it is difficult to develop sound recommendations for water purification systems, acid injectors, micronutrient additions, and in some cases, macronutrient management. Are you recirculating your water? More and more, greenhouses are voluntarily or involuntarily moving towards complete recirculating systems because of environmental considerations. These systems can be extremely efficient, environmentally friendly, labor saving devices, or enormous headaches if improperly designed that wind up costing both in terms of labor and environmental impact. If used, more frequent measurements of water and potential pathogens are made and preventative maintenance is a must.

FERTILIZER

Assuming you have selected your irrigation method and media type and are pleased with the water quality, how should fertilizer programs be selected? There are 18 essential elements, including silicon, that need to be present for the plant to grow well and withstand typical stresses. Three of these, carbon (C), hydrogen (H), and oxygen (O) are acquired through the air (CO_2 and O_2) or water (H_2O). Carbon dioxide (CO_2) can and should be added in some instances, a point I will touch on in another seminar (Greenhouse Environment: Heat and Light). Chlorine (Cl) and nickel (Ni) are usually present in sufficient quantities as contaminants in soilless media, water, or fertilizer to make their additions unnecessary. The remaining "essential" elements are Nitrogen (N), phosphorous (P), potassium (K), calcium (Ca), magnesium (Mg), and sulfur (S), the so called macronutrients, and iron (Fe), zinc (Zn), copper (Cu), molybdenum (Mo), manganese (Mn), boron (B), and silicon (Si), the micronutrients.

MACRONUTRIENTS

Nitrogen and P are used in each protein, genetic event, and growth and development event in the plant, and K is used, among other things, to help support these proteins and genetic material and control water in and out of the plant. Because of this, it is no surprise that the most attention and research has been given to N, P, and K in the macronutrients. Nitrogen is the only element that can be taken up either as a negative (anion) or positive (cation) ion, usually as nitrate ($NO3^-$) or ammonium ($NH4^+$). This difference is incredibly important because it has profound impacts on the media or solution pH and subsequent availability on other nutrients. Figure 1 is an oversimplification of what happens when a root takes up nitrate or ammonium. When nitrate is taken up, the root zone becomes more basic (higher pH) and when ammonium is taken up, the root zone becomes more acidic (lower pH). To further complicate matters, we can't just add a 50-50 mix of each and balance the pH because plants generally take up ammonium first and very quickly causing pH to fall, even if nitrate is present. This can lower the pH of the rhizosphere (area immediately surrounding the root) to 4 or lower, and lower the whole nutrient solution of a hydroponic system by 2 or more pH units.

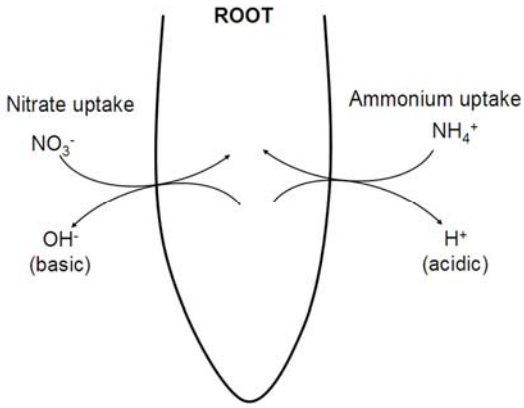

Figure 1. Nitrogen uptake by a root in its two dominant forms.

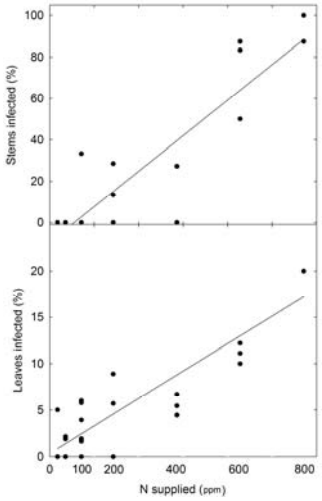

Figure 2. As nitrogen supply increases above 100 to 200 ppm, plant quality decreases and the crop becomes more susceptible to Botrytis

Some crops prefer high N in fertilizers and others do not need as much. As a general rule of thumb, 100 to 200 ppm (100 to 200 mg liter^{-1}, 7 to 14 mM N) on a continuous feed can supply sufficient N to a crop. There is a tendency to over fertilize or over feed a crop to "green it up" and ensure against any yellowing of leaves. While this can provide that insurance, you may be making the plants more susceptible to insect or pathogen damage. Our results indicate, with low feeding plants (100 to 200 ppm requirement), significantly more grey mold (*Botrytis cinerea* spp.) can occur on plants regularly receiving 200 ppm or higher N.

Other than altering pH, the form of N can greatly influence the uptake of other nutrients. Generally, like-charged ions inhibit each other's uptake. For example, ammonium can inhibit Ca and Mg uptake while nitrate can inhibit phosphorus uptake. This is one of the contributing factors to tipburn in lettuce and blossom end rot in tomatoes; the severity of both can be lessened by using low ammonium or ammonium free fertilizers.

What if, instead of a constant feed program, you can only feed your plants weekly? If you feed weekly, you should raise the concentration of your fertilizer solution by roughly 3 fold. So, if you want a constant

feed rate of 100 ppm N, but can only supply a once a week spike, feed with 300 ppm N. This is assuming watering about 3 times per week with 10 to 20% leaching fraction. The pots will leach more nutrients immediately after the fertilizer event, so if you need to monitor the runoff, expect more fertilizer in the runoff after the spike.

As more production is shifted from soil-based to soilless media and more attention is paid to the environmental impact of agriculture and greenhouse runoff, the requirement for phosphorus has decreased. A common N:P (as P_2O_5) ratio is 2:1, but most crops can probably do well with much lower P, for example 4:1 or even 10:1. Check recent publications on the phosphorus requirement for your specific crops, as well as EPA restrictions on P runoff.

Potassium (K) is readily taken up by plants and tissue content can be as high as 8% of the dry weight in lettuce, for example without detrimental growth effects. In other words, if it is present, a plant will take up K whether it needs it or not. A useful guideline is to supply K in a 1:1 ratio with N. Remember the effects that similar charged ions can have on the uptake of others!

The second three macronutrients, Ca, Mg, and S, are often supplied, in soilless media, as pre-planting amendments through liming. For vegetable production, Ca content can be tricky. Calcium deficiencies can occur even if 'sufficient' Ca levels are present. In fact, we can even make these conditions worse if we add more Ca to the media or solution. While it is important to supply enough Ca to the plant, at times Ca uptake can be stimulated by different environmental management and avoiding too many cations (i.e., too much NH_4^+-N). Shade and elevated humidity may exacerbate Ca deficiency, so care must be made to avoid these environments. Paradoxically, low light and elevated humidity may help eliminate tip burn in lettuce because relatively more Ca would move to the growing point where it is most needed.

Magnesium and S, along with Ca, can be supplied in the form of dolomitic lime and gypsum. Watch out for leaching of S – a pre-plant fertilization treatment may not be enough to supply enough S for an entire 2 month rotation if leaching fractions are significant.

MICRONUTRIENTS

There are many products designed to supply all or part of the required micronutrients and many can be supplied once, when the media is mixed, without deficiency symptoms. Fe is an exception to this, and Fe requirements can vary greatly from species to species. Overwatering, heavy media, poor aeration, and poor pH control can also manifest themselves as Fe deficiency symptoms (yellowing of new or expanding leaves). Make sure a different management strategy is not the culprit when correcting for this problem, and if Fe needs to be added, try a chelated form of Fe such as EDDHA or DTPA. The good news is that Fe chlorosis can disappear, if treated either through water management or Fe application, in a matter of days with little or no loss. Zinc and Cu can also be added as chelated forms.

Boron is another micronutrient that can cause problems. Boron is often present in sufficient quantities in the water supply; if your water has anywhere from 0.1 to 0.8 ppm B, you may not need to add any more B. This range is somewhat narrower than commonly reported because I have seen B toxicity when the water supply had only 1 ppm. Be careful of B in the fertilizer as a contaminant, and if composted material is used, B may be present in sufficient to toxic levels. Have your water and media tested for B regularly.

Silicon is a nutrient that some refer to as a beneficial nutrient for some species while others call it essential. There is a growing body of evidence that plants supplied with Si can withstand fungal pathogen attack much better than those grown without Si. Some of the horticulturally important crops that respond favorably to Si additions include cucumber, poinsettia, roses, zinnia, and strawberry, but many crops have

not been investigated yet. Silicon allows for better use of Mn supply, and if you suspect Mn toxicity, supplying Si can protect against Mn toxicity. Silicon is taken up as monosilicic acid or H_4SiO_4, but it is not highly soluble. A supply of 100 ppm Si (3.4 mM) appears to be sufficient for most crops investigated. Silicon can be supplied as potassium silicate, sodium silicate, silicic acid, and some granular forms.

Manganese and Fe deficiencies can become problems in the presence of ozonation systems. If you are using or are thinking of using this purification technique, be aware that available Mn will decrease after the process. Again, measure frequently to keep on top of Mn and add as needed.

SLOW RELEASE OR CONTROLLED RELEASE FERTILIZERS

In some areas, the use of slow release or controlled release fertilizers (CRFs) is common. Due to increasing environmental restrictions, there is tremendous potential in its use because less fertilizer is lost through leaching. When used, half or two thirds of the total nutrients are supplied with CRFs and the rest is supplied as liquid feed. If you are interested, try it on a small number of plants to see how you like it. There are many CRFs with different leaching times, so depending on the crop and market demands, choosing the right CRF will greatly influence the success you have.

FOLIAR APPLICATION

Many growers want to know if they can apply nutrients with foliar applications. There is a great desire among horticulturists to spray our problems away. I would not recommend foliar applications for any of the macronutrients, although there have been successful applications of Ca. Generally, so much of a macronutrient is needed and so little is taken up through the leaf that no real affect would be seen for most circumstances in macronutrient deficiency. Foliar sprays for Cu, Fe, Mo, and Mn are frequently recommended for correcting deficiencies of these nutrients.

MEASURING NUTRIENTS IN THE GREENHOUSE

Foliar analysis was covered in another section (Nutritional Deficiencies: What They Look Like), so it will not be discussed here. The easiest way to get analysis for your water and soil samples is to send it to a professional laboratory for analysis. This can be expensive, especially if you are curious about nutrient status often or want to keep a close eye on how nutrients change over time or with different management practices. For these instances, it may be a wise investment for an operation to purchase on-site measuring capabilities.

There are a few commercially available ion-selective electrodes that do an adequate job of tracking trends in nutrients such as K and NO_3^- and can be purchased for a couple of hundred dollars. Many are sensitive to other, interfering ions, and can be pH and temperature sensitive. Some of the more expensive electrodes are far more accurate and repeatable with a larger measurement range, but require more frequent calibration and possibly replacement of membranes. We have had a nitrate electrode for 12 months longer than it was supposed to last, and have measured thousands of samples with it.

If you want to avoid electrodes and the training and maintenance usually associated with them, there are good colorimetric test strips, much like pH indicating strips, available for specific ions. These can be as accurate as the best electrodes, but their use may be limited because of age of the strip, interfering ions, and temperature of solution, much like electrodes. If a grower wants to invest in the thousands of dollars for testing equipment, there are excellent spectrometric- or colorimetric-based instruments that can detect a wide range of ions, with different indicating solutions, with few significant interferences. A dedicated area and perhaps dedicated technician to operate the equipment may be necessary, but nearly real-time

monitoring can be achieved. A new area of research called "bio-monitoring" holds promise to use a plant's genetic responses to stress as an indicator for specific nutrient stresses, or use "bio-indicating plants" to indicate stress. Hopefully, these systems will begin to be ready in the next couple of years. Overall, I can't overstate the importance of regular monitoring, beyond pH and EC, or your plants, media, and water to get the best production and quality possible for your system.

USEFUL REFERENCES

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Nelson, P.V. 1998. Greenhouse Operation and Management. 5th edition. Prentice Hall, Upper Saddle River, NJ.

http://www.usu.edu/cpl/ click on the hydroponics link for more information

http://aggie-horticulture.tamu.edu/greenhouse/nursery/guides/index.html lots of information

http://www.utextension.utk.edu/publications/horticulture/default.asp#greenhouses there is much more in the main utextension website.

http://www.cropking.com/ good for hydroponics

http://www.scottsprohort.com/ good information on fertilizers

http://www.hydroponics.org/ chat room features

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