Fertilizer Management - Macronutrients

There is a general ratio of macronutrients to maintain in the root medium. Inputs from the water, fertilizer and root medium must be considered.

The macronutrients are
- Nitrogen (N as NO_3 and NH_4)
- Potassium (K)
- Magnesium (Mg)
- Phosphorous (P)
- Calcium (Ca)
- Sulfur (S)

There are many fertilizer salts. There must be a system to decide which to use. On the following pages are a summary table of common macronutrient fertilizers and a listing of Peter's commercially blended water soluble fertilizers.

There are five things to consider in selecting a water soluble fertilizer:
- Balance of nutrients
- Nitrogen reaction and effect on media pH
- Nitrate versus ammonium nitrogen
- Solubility of salts and the mixture
- Effect on nutrient intensity or electroconductivity

Balance of Nutrients

The ratios on the fertilizer bag represent the amount of nitrogen, P_2O_5 and K_2O. P_2O_5 is only 44 percent phosphorous and K_2O is 83% potassium. So, for a 20-20-20 fertilizer, the nitrogen-phosphorous-potassium ratio is 20-8.8-16.8 or 2.3-1-1.9. The effect of fertilizer on soil test levels and analytical results are reported in parts per million or ppm and change more in relation to the applied ppm ratio.

While there are many different commercially available blends of water soluble fertilizers recommended for a specific crop, the majority of crops in peat-based media can be grown with one nutrient ratio. Only a limited number of solutions should be necessary.

In the majority of cases, the sum of the nutrients in the irrigation water and fertilization program for peat- or bark-based media amended with phosphorous, calcium and magnesium should approach the following ratio:

Nutrient Ratios

	N	P	K	Ca	Mg	S
ppm ratios	13	1	13	7	2	2
Example ppm	200	15	200	100	30	30

In these examples all the elements were either cut in half or doubled. This is what typically happens when fertilizer rates are reduced or increased. It is how changes have traditionally been made. It usually results in excess phosphorous, calcium, magnesium and sulfur being applied when high nitrogen and potassium are added under rapid growth conditions.

Cutting All in Half

	N	P	K	Ca	Mg	S
ppm ratios	13	1	13	7	2	2
Example ppm	100	7.5	100	50	15	15

Doubling All

	N	P	K	Ca	Mg	S
ppm ratios	13	1	13	7	2	2
Example ppm	400	30	400	200	60	60

In this example nitrogen and potassium are changed in concentration while the others are not. This example is what I recommend based on research at MSU and my experiences. Our research indicates that maintaining phosphorous, calcium, magnesium and sulfur at a similar level while changing nitrogen and potassium as the amount of growth desired changes provides for more efficient nutrient utilization and perhaps easier management.

Cutting Only N and K in Half

	N	P	K	Ca	Mg	S
ppm ratios	6.7	1	6.7	6.7	2	2
Example ppm	100	15	100	100	30	30

Doubling Only N and K

	N	P	K	Ca	Mg	S
ppm ratios	27	1	27	6.7	2	2
Example ppm	400	15	400	100	60	60

Following are some general rules to consider:

The ratio of nitrogen to potassium in ppm is typically 1:1. This ratio may change depending on the plant species, but it will be in the range of 1N : 0.3K to 1N : 3K. The "K ratio" is the ratio of nitrogen to potassium with nitrogen as 1. A 20-10-20 fertilizer has a K ratio of 0.8 since the fertilizer is 20 percent K_2O and K_2O is 83 percent potassium. Potassium nitrate (13-0-44) has a K ratio of 2.8. This is calculated by dividing 36 percent potassium by 13 percent nitrogen.

Phosphorous of 10 to 20 ppm is recommended for constant liquid fertilization. The amount of phosphorous in the most popular water soluble fertilizers has changed from 15-30-15 to 20-20-20 to 20-10-20 over the last 50 years. It has now gone to 20-5-20 (13-2-13) since high rates of phosphorous are not needed in peat- and bark-based media if the pH is less than 6.5.

At 200 ppm nitrogen from 20-10-20, there would be 44 ppm of phosphorous. This is probably four times more than is necessary in most situations. At 200 ppm from 13-2-13, there would be about 13 ppm phosphorous which is sufficient. Even at 100 ppm nitrogen, there should be adequate phosphorous (7 ppm) for most situations. The additional phosphorous is not detrimental to the plant. However, it is costly and a potential environmental contaminant if it leaves the greenhouse in runoff.

Concentrations of 15 ppm phosphorus, 100 ppm calcium and 30 ppm magnesium and sulfur are recommended to keep levels in balance after starting with a balanced charge in the root medium. The concentration of nitrogen and potassium can change from 100 to 300 ppm while the levels of phosphorus, calcium, magnesium and sulfur stay constant.

A balanced solution containing calcium, magnesium, phosphorous and sulfur will require multiple stock tanks or special formulations. Calcium and phosphorous can only be mixed in the same stock tank if the pH of the stock fertilizer solution is less than 2.5. Otherwise, two stock tanks are required. This can be done 1) by adding phosphorous in the form of phosphoric acid; 2) by adding phosphorous in the form of Ureaphosphate as is done in the Excel fertilizers; or 3) by adding a granular acid to the fertilizer salts as is done with GreenCare fertilizers.

There is no indication that sulfur levels up to 100 ppm constant from sulfuric acid will lead to nutrient imbalances or reductions in calcium availability in peat-based media. Sulfur is rarely limiting to plant growth. Levels of 10 ppm are adequate. This is possible from 1/3 of an ounce per 100 gallons sulfuric acid. While additional sulfur is recommended, it is often not required. It may be present in the irrigation water and/or root medium. Calcium and sulfur cannot be mixed in the same 100x stock tank solution.

The effect of sulfate on calcium solubility in water lines and irrigation systems may lead to a problem with accumulation of calcium sulfate deposits.

Nitrogen Reaction and the Effect on Media pH

The second consideration in selecting a water soluble fertilizer is the nitrogen reaction and the effect on media pH.

Each fertilizer will have a neutral, acidic or basic reaction in the root medium. The main difference in the relative acidic or basic nature of water soluble fertilizers is the amount of nitrate versus ammonium nitrogen. The greater the amount of ammonium nitrogen, the more acidic the fertilizer. The acidic or basic reaction is primarily dependent on how the fertilizer is absorbed by the plant. Therefore it is often called *physiological* acidity or basicity.

For example, one pound of ammonium nitrate (34% N) dissolved in the medium and used by the plant will neutralize 0.6 pound of limestone while one pound of ammonium sulfate (21% N) will neutralize 1.1 pounds of commercial limestone, calcium carbonate. To apply the same amount of nitrogen fertilizer with ammonium sulfate would require over 1.6 pounds of fertilizer or the equivalent of 1.8 pounds, or three times more, lime.

Ammonium nitrogen can changed to the nitrate form by bacteria in a process known as nitrification.

Or it can be taken up by the plant as ammonium, NH_4^+.

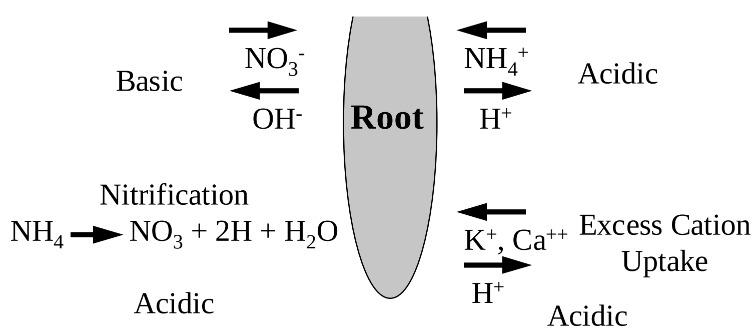
Excess nitrate uptake increases medium pH due to hydroxide from the root.

Excess ammonium uptake decreases medium pH due to hydrogen from the root.

There is a balance of nitrate and ammonium that will lead to a balanced pH.

High rates of fertilization and cation uptake can also result in a lowering of pH. This is not nearly as common as effects due to nitrate and ammonium nitrogen.

Water Soluble Fertilizer Factors Influencing the Root-Medium pH



Nitrate Versus Ammonium Nitrogen

The ratio of nitrate to ammonium nitrogen (percent ammonium) may also effect plant growth. How much ammonium is used may effect the type of growth. More controlled or “hard” growth is typically associated with 100 percent nitrate nitrogen. Larger leaves or “soft growth” is associated with ammonium nitrogen. Only a small amount of ammonium (less than 15 to 20 percent) is needed to see this change in growth characteristics. Higher rates, 20 to 50 percent ammonium, typically do not result in increased differences in the type of growth.

Solubility of the Salts and the Mixture

Another consideration is the solubility of the salts and the mixture.

Not all elements can be mixed. Generally calcium and phosphate are not mixed in the stock tank. Calcium and phosphorous can only be mixed in the same stock tank if the pH of the stock fertilizer solution is less than 2.5. Otherwise, two stock tanks are required. This can be done 1) by adding phosphorous in the form of phosphoric acid; 2) by adding phosphorous in the form of Ureaphosphate as is done in the Excel fertilizers; or 3) by adding a granular acid to the fertilizer salts as is done with GreenCare fertilizers.

Calcium and sulfur cannot be mixed in the stock tank. The effect of sulfate on calcium solubility in water lines and irrigation systems may lead to a problem with accumulation of calcium sulfate deposits.

Potassium nitrate is usually the hardest salt to dissolve in high concentrations, but water temperature can make a big difference. Use warm water when possible.

Effect on Nutrient Intensity or EC

Although it is not commonly done, we can also consider the effect on nutrient intensity or electroconductivity.

Not all fertilizer salts will have the same solution electroconductivity or effect on media electroconductivity. Different fertilizers applied at the same nitrogen concentration may result in different root medium EC values. Evidence demonstrating this principle is provided in the BPFI Research Report included in this booklet.

Summary

Selecting fertilizers can be done most efficiently by considering

- the “K” ratio
- the “N” reaction or effect on media pH
- the amount of ammonium nitrogen

Fertilizer Management - Micronutrients

Micronutrients include:

- Iron (Fe)
- Manganese (Mn)
- Zinc (Zn)
- Copper (Cu)
- Boron (B)
- Molybdenum (Mo)
- Chloride (Cl)

Micronutrient fertilization has not received much attention in the past few years. With regular application of micronutrients to the root medium, regular application in water soluble fertilizer, and proper medium pH management, there should not be routine micronutrient problems.

There are occasionally problems when something accidentally gets left out or the root medium pH is either too high, resulting in toxicities, or too low, resulting in deficiencies.

The key to micronutrient management is to keep it simple! There is a wide range of acceptable ratios. Just make sure that all micronutrients are present!

For example, in several commercial products, the iron to manganese ratio may vary from 1 : 1 to 2 : 1 to 4 : 1 or 12 : 1 or even 16 : 1; yet all seem to work reasonably well.

With reductions in the rates of water soluble fertilizer from 200 to 300 ppm down to 100 to 150 ppm, the amount of micronutrients applied is reduced. Most water soluble fertilizers have been designed for proper application of micronutrients at 200 ppm nitrogen. When they are used at half that rate, the micronutrient concentrations are cut in half. Lower fertilization rates may also result in high root medium pH.

The answer may be for fertilizer companies to adjust the formulation of water soluble fertilizers to include more micronutrients in blends that are to be used at lower nitrogen fertilization rates.

As a grower, keep track of micronutrients and check what rate you are applying.

Some things to consider in micronutrient management are:

- Nonchelated micronutrients added to high pH or high alkalinity water will probably not stay soluble. They may precipitate from a stock solution and end up on the bottom of the tank. Use either purified (rain) or acidified water to make the stock solution in this case.
- It is very possible to over apply micronutrients. Boron toxicity is not uncommon. Make sure you know how much boron is in the irrigation water. Some plant species,

for example geranium and marigold, will accumulate iron and manganese if the medium pH gets much below 6, resulting in a toxicity of these elements.

- Root medium pH influences micronutrient availability differently. Iron, manganese, zinc and molybdenum tend to increase in availability as the pH increases. Boron and copper uptakes are not influenced much by medium pH.
- Tissue analysis is a better check of micronutrient availability than media analysis. When it comes to testing the availability of micronutrients, remember that the concentration of micronutrients extracted from a root medium sample can change by changing the medium pH without changing the amount of micronutrients being applied.

How Much Fertilizer to Apply

There are several methods to determine how much fertilizer to apply to a given crop. You can get the information from

- Textbooks
- Extension publications
- Trade journal articles
- By talking with other growers who have experience
- By trail and error
- By experimentation

In most cases, starting with a standard rate of 150 to 200 ppm of nitrogen and a balanced solution is recommended. Then make adjustments based on the appearance of the plants and soil test values. It is possible that, with a rapidly growing plant and very low soil test values, as much as 600 ppm of nitrogen may be appropriate. With low nutrient crops, as little as 50 ppm of nitrogen may be necessary.

There are at least four factors that may influence the rate of water soluble fertilizer needed to maintain plant growth.

Rate of leaching - The nutrient concentration for container grown plants is a function of both concentration applied and the volume that is applied and drains through the medium and out of the pot. Leaching fraction or leaching percentage is the amount of water draining out the bottom of the container as a percent of the amount of water applied. If 10 fluid ounces are applied and one ounce drains out, the leaching percentage is one divided by 10 times 100 or 10 percent. The larger the leaching percentage, the higher the concentration of fertilizer needed to maintain a given concentration of nutrients in the root medium.

Rate of growth in response to stage of crop development - Initial growth of seedlings or transplants is limited by the size of the plant, so less fertilizer is required. When the plant is growing the fastest, more nutrients are required. However, in the case of constant water soluble fertilization, more water is also being applied, so the concentration of the fertilizer usually does not need to be changed.

Rate of growth in response to environmental conditions - When light and temperature are optimum, the rate of growth will be faster and therefore the requirements for nutrients will be greater. However, in the case of constant water soluble fertilization, water will also be applied more frequently under warm, bright conditions, so the nutrient concentration usually does not need to be changed. Does the fertilizer concentration need to be changed if watering occurs less frequently in the winter? The answer is no if the plants look healthy.

Type of plant - Over time, certain plants have been labeled as either “light,” “moderate,” or “heavy” feeders. This designation most likely was made prior to the use of constant liquid fertilization. While faster and larger growing plants may require more fertilizer, these plants generally also use more water. If leaching is controlled and fertilizer is applied at every irrigation, fertilizer is applied more frequently rather than at higher concentrations. Most species of flowering pot plants grown in the greenhouse today can be grown with similar levels of nitrogen applied at every irrigation.

Crops can be characterized as either fertilizer, or nitrogen, tolerant or intolerant. It is also important to know whether they will get larger with increased fertilizer or show little growth response to increased nitrogen.

Chrysanthemums and petunias are tolerant of higher fertility levels and will continue to get larger as fertility levels are increased.

Poinsettias and marigolds will tolerate higher fertility levels but show little increase in growth in response to the increased nitrogen. Poinsettias may actually show reductions in plant size.

African violet and New Guinea impatiens are examples of plants that are intolerant of increased fertility.

Many growers have managed with simple formulas, like one bag per stock tank, without knowing how many ppm are being applied. It is not that difficult to determine how much fertilizer is needed to apply a desired ppm.

Calculations for the amount of fertilizer can be done using:

- Formulas - we’ll be working through some examples.
- Look-up tables - these are available for blended fertilizers and fertilizers made from salts on site with calculations already done.
- For EC based injectors, the electroconductivity of the final desired solution must be known or calculated. The EC of individual salts can be added together to get the EC of the combined salts.

To predict the EC of the fertilizer solution:

- Measure EC of the tap water. For example, MSU tap water is 0.65 mS cm^{-1}.

- Add the EC of the water to the EC of the desired fertilizer concentration. For example, 20-10-20 at 150 ppm N has an EC of 0.94 mS cm^{-1} in pure water.
- EC of the water (0.65 mS cm^{-1}) plus EC of fertilizer (0.94 mS cm^{-1}) equals EC of the solution (1.59 mS cm^{-1})

To determine the concentration of fertilizer solution from the solution EC:

- Determine the EC of your tap water. For example, MSU tap water is 0.65 mS cm^{-1}.
- Subtract the EC of the water from the EC of the solution. For example, 20-10-20 coming from the injector has an EC of 1.59 mS cm^{-1} .
- EC of the solution (1.59 mS cm^{-1}) minus the EC of the water (0.65 mS cm^{-1}) equals EC of the fertilizer (0.94 mS cm^{-1}). This corresponds to a fertilizer concentration of 150 ppm N from 20-10-20.

Fertilizer Calculation Formulas

For a given concentrate tank size and known injector dilution factor (examples: 15 (Hozon); 50, 100 (Smith, Dosatron, Dosamatic); or 200) use the following two formulas.

- If no injector is used, enter the gallons of diluted fertilizer desired in place of gallons of stock and a dilution factor of one (1).
- For elemental percentages in a fertilizer, use the whole number, not the decimal. For example, for 20-10-20, use 20% nitrogen, not 0.20.
- To convert small weights from pounds to ounces, multiply the final answer by 16 ounces per pound, or convert to grams by multiplying pounds by 454 grams per pound.
- For calculations with elemental N, K, P, or any element, “A” equals 1200. If the $\%K_2O$ is used rather than elemental %K, use “A” equals 1000 in place of 1200. If the $\%P_2O_5$ us used rather than elemental %P, use “A” equals 500 in place of 1200.

To determine the pounds of fertilizer needed to achieve a desired ppm, use this formula:

(desired ppm) x (gallons of concentrate) x dilution factor
-- = lbs of fertilizer
(whole number % element in the fertilizer) x (A)

Example: How many pounds of fertilizer are needed to supply 200 ppm N from 20-10-20, using a 50 gallon concentrate tank and a 1 to 100 dilution injector?

(200 ppm) x (50 gallons of concentrate) x (100 dilution factor)
--- = 41.7lbs of fertilizer
(20 % N) x (1200)

To determine the ppm supplied from a known amount of fertilizer, use this formula:

$$\frac{\text{(whole number \% element in the fertilizer) x (lbs of fertilizer) x (A)}}{\text{(gallons of concentrate) x (dilution factor)}} = \text{ppm}$$

Example: How many ppm of actual P are supplied with the 200 ppm nitrogen from the 41.7 pounds of 20-10-20 in 50 gallons stock for 100x dilution above?

$$\frac{\text{(10 \% }P_2O_5\text{ in the fertilizer) x (41.7 lbs of fertilizer) x (500)}}{\text{(50 gallons of concentrate) x (100 dilution factor)}} = \text{42 ppm P}$$

Fertilizer Calculation Example

Question: How much potassium nitrate and calcium nitrate are needed to make 50 gallons of stock for a 1 to 100 injector so that 200 ppm of nitrogen and potassium are applied?

Answer: Start by looking up the nitrogen and potassium content of the two fertilizers. Potassium nitrate is 13-0-44 and calcium nitrate is 15.5-0-0. Only one of the fertilizers has potassium, while both have nitrongen, so start with estimating the amount of potassium nitrate required to get 200 ppm potassium. Potassium nitrate is 44%K_2O, so A=1000.

$$\frac{\text{(200 ppm K) x (50 gallons of concentrate) x (100 dilution factor)}}{\text{(44 \% }K_2O\text{) x (1000)}} = \text{22.7 lbs of fertilizer}$$

To determine the ppm nitrogen supplied from the potassium nitrate, use formula two. Potassium nitrate is 13% elemental nitrogen, is A=1200.

$$\frac{\text{(13\% N in the fertilizer) x (22.7 lbs of fertilizer) x (1200)}}{\text{(50 gallons of concentrate) x (100 dilution factor)}} = \text{71 ppm N}$$

The remaining part of the nitrogen (200 ppm – 71 ppm = 129 ppm) can come from the calcium nitrate. Calcium nitrate is 15.5% elemental nitrogen, so A=1200.

$$\frac{\text{(129 ppm N) x (50 gallons of concentrate) x (100 dilution factor)}}{\text{(15.5 \% N) x (1200)}} = \text{34.7 lbs of fertilizer}$$

Question: How much calcium would this provide?

Answer: Look up the percent calcium in calcium nitrate and use formula two. Calcium nitrate is 19% elemental calcium, so A=1200.

$$\frac{(19\%\text{ Ca in the fertilizer}) \times (34.7\text{ lbs of fertilizer}) \times (1200)}{(50\text{ gallons of concentrate}) \times (100\text{ dilution factor})} = 158\text{ ppm Ca}$$

How much potassium nitrate and calcium nitrate are needed to make 50 gallons of stock for a 1 to 100 injector so that 200 ppm of nitrogen and potassium are applied?

The answer is 22.7 pounds of potassium nitrate and 34.7 pounds of calcium nitrate in a 50 gallon stock tank with a 1 to 100 injector will provide 200 ppm nitrogen and potassium and 158 ppm calcium.

Checking Injectors

It is very important to check the injectors.

Fertilizer injectors are the most common sources of problems in root zone management. Injectors must be maintained and checked. The EC of fertilizer solutions should be checked regularly. Tables of expected EC values for a given fertilizer at a given concentration are available. Regularly send fertilizer solution samples to an analytical lab to be checked.

EC based injectors must also be checked regularly with a second meter. The EC probe must be checked monthly at the minimum and calibrated if needed.

Summary:

- The root medium nutrient content depends on preplant fertilization and irrigation method.
- Consider each crop, including how much fertilizer is needed and the crop’s response or tolerance to low and high fertilizer.
- In many cases fertilizer is applied in response to the amount of growth occurring and not to stimulate more growth.
- In some crops fertilizer is used to control the size of the plant.
- Over application of nitrogen and phosphorous needs to be avoided. This is the simplest and most cost effective method of preventing fertilizer contamination of the environment. With careful application of fertilizer, there is little or no need for expensive recovery and recirculation systems.

Root Medium pH Management

The root medium pH influences the availability of nutrients to the plant. The hydrogen (H^+) and hydroxide(OH^-) concentrations are small but important.

Let's review what we mean by pH. It is a measure of the relative number of hydrogen and and hydroxide ions. If the number of hydrogen ions and hydroxide ions are equal, the pH of the solution is neutral or 7.0. If there are more hydrogen ions present than hydroxide ions, the solution is acidic and has a pH of less than 7.0. If there are more hydroxide ions present than hydrogen ions, the solution is basic and has a pH of greater than 7.0. The pH of a solution tells us something about the water (H_2O) and what will dissolve in it.

Root medium pH is influenced by many factors including:

- Components of the root medium
- Lime
- Water quality
- Type of nitrogen
- Amount of fertilizer
- Crop species

The research report from the Bedding Plant Foundation included in the handout has a summary of how water, fertilizer type and lime interact to determine root medium pH.

There are two strategies that growers can employ in managing root medium pH.

One approach to pH management with high alkalinity water is to start with a low, 5.5 or less, root medium pH at planting and allow the medium pH to increase over time. Alkalinity of the irrigation water or pH of the root medium are not adjusted downward until the medium pH becomes high, greater than 6.5 or 7.0. The advantage of this technique is that less acid is used. The disadvantage is knowing when to make the adjustments before the medium pH gets too high and crop growth is limited. If a variety of crop species or planting dates are present in the same greenhouse, keeping everything adjusted correctly is difficult.

An alternative strategy is to start the pH at the desired level and adjust the water alkalinity and fertilizer program so pH will remain constant and no major changes are necessary. Some crop species will tend to have a basic or acidic effect on the root medium pH. In these limited cases, adjustment of the root medium, more or less lime, should be the first strategy to manage pH. Adjustments in irrigation water alkalinity and/or water soluble fertilizer nitrogen form may then be necessary for certain crops.

Raising Media pH

There are several alternatives for raising media pH.

- Nitrate nitrogen will gradually raise the pH. However, it is not very effective is the pH is more than two or three tenths low. High rates of fertilizer, 300 to 400 ppm nitrogen for example, may actually be acidifying in some cases.
- Hydrated lime or flowable lime - Recommendations range from one pound per 100 gallons to one pound per five gallons, with direct application of only the clear solution after insoluble materials settle to the bottom. This solution cannot be applied or diluted with an injector. Applications of flowable lime suspensions or hydrated lime are often not very effective due to the limited solubility of these materials in water. They may be more effective if used in low calcium, magnesium, low alkalinity water.
- Potassium bicarbonate - If root medium pH is below 5.5 due to a lack of preplant lime, the use of acid fertilizers or the growth of crops that acidify the medium, potassium bicarbonate or potassium carbonate are the most soluble materials that can be applied as a drench to rapidly raise the medium pH.

Using Potassium Bicarbonate to Raise the Root Medium pH from Values Less than pH 5

- Larger amounts are needed than most growers expect. Two pounds per 100 gallons can go through an injector. Four to eight pounds per 100 gallons must be dissolved in a drench tank.
- Multiple applications may be necessary if the pH is less than 5.0.
- Drenches should be applied directly to the medium, avoiding contact with foliage and flowers.
- Rinse any solution residue from foliage before it dries. Even at the lowest rate, the solution may damage plant foliage if allowed to dry.
- Each one pound per 100 gallons will provide approximately 400 ppm additional potassium, so a follow up leaching with calcium and magnesium fertilizer may be necessary to re-establish the cation balance.

Lowing Media pH

In cases where it is necessary to lower pH, there are several alternatives.

- Ammonical nitrogen (ammonium sulfate) will gradually lower pH, but the crop must be able to tolerate the nitrogen.
- Inorganic acids such as sulfuric acid can be used to acidify irrigation water. Use more than what is needed to control alkalinity.
- Iron sulfate can be applied, but it is not very effective if the pH is above 7 unless high rates are used.
- Elemental sulfur is a safe way to lower pH. It has a reaction time and the exact recommendations for using it are unknown.

To lower root medium pH by acidifying irrigation water,

- All the bicarbonate alkalinity in the water must first be neutralized. When all the bicarbonate is neutralized, the pH of the solution will be approximately 4.0 to 4.5.

- Additional acid is then added to neutralize the basic compounds in the medium, 500ppm if medium pH greater than 6.5 but less than 7.0, to 1000 ppm if the medium pH is greater than 7.0. The additional acid will lower the irrigation water or fertilizer solution pH to 2.5 to 3.5.
- The low solution pH is necessary but it makes it essential that the solution be used carefully and is washed off plant foliage before it dries.
- After one hour, test the root medium pH. If additional change is needed, apply additional drenches until the desired pH is attained. Test this procedure on a small group of plants. The amount of acid required or the number of drenches needed will partially depend on the length of time the medium pH has been above 7.0. If the medium pH is at the desired range one hour after drenching, it should be checked again after 24 hours, since some slow reaction will continue. The pH of the leachate from the bottom of the pots can be used as a measure of the effectiveness of the drenches. If the solution goes in the pot at pH 2.0 but the leachate draining out is 7.0 or greater, more leaching is probably necessary.

Summary of points related to managing root medium pH:

- Managing pH is one of the most important root zone management responsibilities.
- Root medium pH is influenced by many factors including:
    - Components of the root medium
    - Lime
    - Water quality
    - Type of nitrogen
    - Amount of fertilizer and
    - Crop species
- Keeping the pH in a desired range by making minor adjustments to the program is better than making drastic corrections to the pH after it is out of the desired range.

Root Medium Analysis

Why test the root medium? It is important to have values for healthy plants and standard conditions so there is something to compare to if things go wrong. Routine testing will help you keep on track. Diagnostic testing may be needed to correct problems. You need samples to compare. Testing can help determine the effects of changes made to your program, for example going from leaching to no leaching. You can compare the results of tests to plant performance.

What parameters are important to test? Use the General Nutrition Guidelines. You will want to know:

- pH and EC
- Macronutrient concentration
- Macronutrient balance or % of total salts
- Micronutrients - root medium analysis is not always an accurate measure for micronutrients. The results are very pH dependent. It would be better to use tissue analysis.

Perhaps the most common error associated with nutrient analysis of media and plants is improper sampling. The variability in nutrient levels from pot to pot demands that a sample for analysis consist of a mixture of subsamples from at least 10 pots. Basing the management of hundreds or thousands of plants on one or two pots is a serious mistake.

The variability within a pot and the changes that can occur over time also dictate that the sampling position in the pot and the time of sampling relative to an irrigation must be consistent.

Difference Between 1:2 Dilution and Saturated Medium Extract (SME)

There is a growing interest in on site media analysis. Reports from growers doing routine weekly on site analysis tell us that many fertilization errors are caught early and major problems are prevented by keeping a regular measure of pH and electroconductivity. One of the major obstacles is the lack of uniformity when multiple growers or assistants do media analysis from one location versus another or at one time versus another. The best remedy to prevent this problem is to have one person do all the sample collection and analysis for consistency.

A second obstacle is the lack of understanding about the difference between extraction methods. Most on site analysis is done with a 1:2 dilution while most analytical laboratories are using a saturated extract or SME. The readings for soluble salts can vary by as much as 1.5 to 2.5 between the two methods. One solution is to use the SME method for on site analysis. The SME method is not that difficult to so and the moisture content and volume of media used are not sources of variability as they are with the 1:2 dilution method. The limitation has been the ability to extract enough solution from the extract for EC measurement; pH is read directly in the paste.

There are two methods that can be used to read the EC of an SME sample on site.

One option is to purchase a meter that requires only a small amount of solution to obtain a reading. One example is the Cardy pen type meter, but there are other examples. A small dropper or pipette can be used to draw up enough solution from the saturated medium sample.

A second option is to place the sample in a piece of cheese cloth and squeeze out a sample of solution. This technique has not been recommended in the past or tested under controlled conditions to verify that readings are the same as with vacuum extraction. However, there are growers using this technique and it seems reasonable that the solution would not be altered by the cheese cloth extraction method.

There are three criteria generally used for determining the point of saturation of a medium sample:
1. The surface of the sample just starts to glisten or become shiny.
2. The sample should start to become fluid, but very little water should be able to be poured off the sample.
3. The sample should easily slide off a metal spatula used for mixing the sample.

It is generally recommended that the samples sit for one hour after saturation to equilibrate. If the medium started out dry and some of the water has been absorbed during the one hour, more water may be need to be added to return to the point of saturation.

With the Cardy meter, a small sample is then collected using a dropper and placed on the electrode. Since a small sample is actually read, it is important that a representative root medium sample is collected and thoroughly mixed before extracting. With the Cardy meter, nitrate and potassium read to the nearest five or 10 will be acceptable.

To many test results end up in a pile of paper on a desk. The results must be compiled, so trends over time can be examined.

This can be done by graphing the information to show trends. Computerization is not necessary to do this, but it does make it easier!

There are limitations to media analyses. The appearance of the plant needs to be considered when interpreting test results.

One limitation is the variation from pot to pot and within the same pot. Another is that good plants can be grown at media analysis levels well below those recommended. Results can be misinterpreted. This is why it is important to consider the appearance of the plant. Accuracy and precision may vary.

Summary:

- On-site methods and laboratory methods have usually been different but can be the same.
- It is important to know what is in the root medium but minimum concentrations do not necessarily have to be maintained for best plant growth.
- Use medium analysis to watch for accumulation of toxic elements like sodium and chloride.

Plant Tissue Analysis

Why is plant tissue analysis a good idea? Making decisions based on the appearance of foliar symptoms can be risky. A symptom can be due to many problems, including over watering, root rot, low or high temperatures and so on. A symptom can be due to the deficiency or toxicity of more than one element, or even the toxicity of a different element. One way to know what you are dealing with is to analyze the plant tissue.

Taking a good sample or samples is the key to using foliar analysis as a diagnostic tool. Many laboratories will provide specific recommendations for how to sample.

Sample position, age of the tissue and the type of tissue will have a great effect. The most recently matured, fully expanded, new leaves are usually sampled. The petiole of the leaf should be consistently included or excluded from the sample. I recommend not including it.

Interpretation guidelines are not generally needed for each crop since levels are mostly the same.

Foliar analysis is a good check of nutrient availability and the fertility program. If plant size is as desired and nutrient levels in the plant are within acceptable levels, the fertility program is probably on track. If nutrient levels are within recommended ranges but the plant is stunted or growth is slow, the nutrient program may need adjustment. While many species have similar nutrient contents, be aware of differences among species and unique to certain crops.

Leaf tissue analysis guidelines are presented in the following table.

Summary:

- Under conditions of low fertilizer application, tissue analysis is more important.
- Understanding nutrient balance and expected tissue concentrations is essential.
- Quick tests for nitrogen are very helpful.

Routine application of water soluble fertilizers to porous root media has helped make root zone management more simple than in the past. However, the need to reduce fertilizer use to prevent contamination of the environment has led to the requirement of applying only what is needed and as efficiently as possible. This type of management requires a better understanding of the principles and practices used for maintaining the root zone of container grown plants.