Are Your Plants On The Right Diet

Some simple guidelines to give your plants the nutrition they need

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Fertilization programs in greenhouses are often taken for granted. Symptoms of nutritional problems often are less obvious than those of insects or diseases. Because of this, nutritional problems may not be recognized or are misdiagnosed. Problems with greenhouse fertilizer programs are very common and can result in decreased quality or a prolonged growing period of the crop, both of which would decrease the profit margin. Clearly, it is crucial to assure that the fertilizer needs of your plants are met, without applying too much fertilizer. Keep in mind that fertilizer concentrations that are too high are just as likely to cause problems as very low fertilizer concentrations.

Just like people, plants need certain nutrients to remain healthy. Obviously, plants have very different nutritional needs than people. Unlike people, plants can make their own carbohydrates, amino acids, and vitamins. What they cannot make themselves are the mineral elements, such as nitrogen, phosphorus, potassium, sulfur, calcium, magnesium, and the various micronutrients. Plants are dependent on the roots to take these nutrients up from the soil or medium that they are growing in (plants also can absorb small amounts of nutrients through their leaves, but this is not enough for plants to stay healthy). Plants growing in nature generally can take up the required nutrients from the soil, but plants in greenhouses and nurseries are dependent on the fertilizer we supply.

When plants were produced in growing media that contained large amounts of natural soil, fertilization was fairly easy. The soil contained the micronutrients and we had to supply enough of the macronutrients, in particular nitrogen, potassium, and phosphorus, to keep the plants healthy. The use of light-weight, soilless media has resulted in dramatic changes in how we need to fertilize plants. These days, the growing media consist mainly of peat or coconut coir, pine bark, perlite, and vermiculite. These components do not supply many nutrients to the plants. Lime normally is mixed into the growing medium, mainly to make sure that the pH of the growing medium is suitable for plant growth (for more about pH, see the section on testing your growing medium). However, a side benefit of lime is that it also supplies calcium and some magnesium. A starter fertilizer is often mixed into the growing medium as well. This supplies plants with all the needed mineral nutrients after they are transplanted into pots or cell packs. However, just as the name starter fertilizer suggests, this fertilizer supplies the needed nutrients to get the plants of to a healthy start. The starter fertilizer is not sufficient to provide nutrients throughout the entire production period. Unfortunately, it is not possible to incorporate all the needed nutrients for the production of strong, healthy plants into the growing medium at the start of the growing season. This would result in very high fertilizer levels (also referred to as soluble salts) in the growing medium, which can damage tender, young roots and weaken the plant. This makes the plants more susceptible to insects and diseases.

The only solution is to provide the plants with the nutrients they need throughout the production cycle. This can be done by incorporating a slow-release fertilizer into the growing medium, or by using water-soluble fertilizers. The disadvantage of slow-release fertilizers is that you don't have any control over it after it has been incorporated. It also is quite a bit more expensive than water-soluble fertilizers, so water-soluble fertilizers generally are the fertilizer of choice in greenhouses.

A well-planned fertilizer program is absolutely critical for the production of high-quality plants. Problems with plant nutrition probably cause more damage to crops than any other kind of greenhouse problem. If nutritional problems are not prevented or detected early, they can make an entire crop worthless. Here, we have summarized some simple guidelines to help you make sure that your plants remain healthy. These guidelines are divided into three sections: how to make sure that you are applying the correct fertilizer concentration, testing of the growing medium, and leaf tissue analysis.

The best method to make sure that your plants have all the nutrients they need, is by sending leaf samples to a lab and have them analyzed for concentrations of the different nutrients. Although this method gives an excellent indication of the current nutritional status of the plants, it does not necessarily help to prevent future problems from occurring, because it does not tell you if there are ample nutrients available in the growing medium to support future growth of the plants.

A better approach to prevent future nutritional problems is by testing the growing medium. This will tell you if there is enough (or perhaps too much) fertilizer available in the growing medium to keep plants healthy as they grow. If the amount of fertilizer in the growing medium is too low or too high, you may have to change the concentration of the fertilizer solution you are using.

That raises the question of whether you really know what the concentration of your fertilizer solution is in the first place. When is the last time that you tested your fertilizer solution? Most growers I have talked to hardly ever measure the concentration of the fertilizer solution. Instead, they simply assume that their fertilizer injector is working properly. We will explain a simple method to determine the exact concentration of your fertilizer solution and to assure that your injector does what you want it to do. Keep in mind that you can't make informed decisions about changing your fertilizer program if you don't know exactly what you are doing in the first place.

Before talking about the different tests you can do to make sure that your fertilizer program is supplying your crop with all the needed nutrients, we will first discuss some basic equipment that every grower should have in their greenhouse.

What equipment and supplies do you need?

To perform some basic tests in your greenhouse, you need only two pieces of equipment: a pH meter and an EC meter (Figure 1). A pH meter is needed to determine how acid or alkaline your growing medium or fertilizer solution is. pH is important because it affects the availability of micronutrients, while EC is a measure of the total amount of fertilizer salts in the growing medium.

pH. The pH is a measure of how acid or alkaline (or basic) the fertilizer solution or growing medium is. It is expressed on a scale from 0 - 14, where 0-7 is the acid range and 7 - 14 the alkaline range. To give you an idea of how acid different fluids are, Figure 2 shows the pH of some common chemicals found around the house.

The pH of the growing medium is much more important than the pH of the fertilizer solution, since the pH of the growing medium determines how available the various nutrients are (see Figure 3). In general, the availability of macronutrients (nitrogen, phosphorus, potassium, sulfur, magnesium and calcium) is not greatly affected by the pH of the growing medium , while the availability of micronutrients does depend on pH. For example, iron and manganese are much more available at low pH than at high pH. Because of this, plants can take up very large amounts of iron and manganese when the pH of the growing medium is low, which can produce toxicity in some sensitive species (marigold is a good example). So keep in mind that there is such a thing as too much of a good thing when you are talking about plants and nutrition!

On the other hand, at high pH manganese, iron, and boron become less available and the plants may not be able to take up these nutrients from the growing medium, resulting in deficiencies. It is important to realize that at high pH deficiencies occur because plants are unable to take up these nutrients from the growing medium, not because the nutrients are not present! Adding more iron, manganese, and boron will not solve the problems associated with high pH, because they will not be available to the plant, even if they are in ample supply in the growing medium. The only solution is to reduce the pH of the growing medium, making those nutrients more available again. The availability of other micronutrients is affected by pH as well, but problems with boron, iron, and manganese are most common.

One example where we take advantage of the effects of pH on the availability of micronutrients is in hydrangea production. The color of the flowers depends on the amount of aluminum in the flowers; with little aluminum, the flowers are pink, while they turn blue with high aluminum concentrations. At low pH (5.0 - 5.5), aluminum is more available to the plants, so the flowers turn blue, while at high pH (6.5 - 7.0) there is little aluminum in the flowers and they will be pink.

To measure pH, you will need a pH meter and two calibration solutions. The price of pH meters starts at about $45, and can be as high as $1,000. Cheap pH meters are good enough for use in greenhouses, but you do need to keep in mind that they may not last very long (if you're lucky 3-5 years, don't count on a lifetime of more than 1 year). For approximately $200, you can get pH meters that will last a long time, and the actual sensor on many of these meters is replaceable, so you don't need to buy an entire new meter when the sensor goes bad. Calibration solutions cost only a few dollars and for use in greenhouses, you should get calibration solutions of pH 4 and 7.

EC. EC is short for electrical conductivity, which means exactly what the name implies. It is a measure of how well a solution or growing medium conducts electricity. When salts (including fertilizer salts) dissolve in water, they conduct electricity (Fig. 4). By measuring how well a solution conducts electricity, we can determine the total amount of dissolved salts in the solution. Since almost all salts in fertilizer are macronutrients, EC can be used as an indicator of the presence of macronutrients, but it gives little or no information about the presence of micronutrients. Like pH meters, the price of EC meters starts at approximately $45 and only one calibration solution is needed for EC meters.

Unfortunately, the units in which EC is expressed can be a bit confusing, although most of them are really the same:

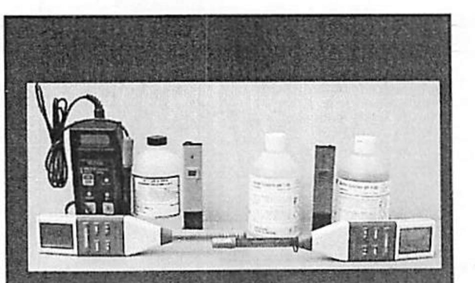

Figure 1. To measure the EC and pH of your fertilizer solution and growing medium, you will need and EC meter, a pH meter and three calibration solutions (one for the EC meter and two for the pH meter). Several EC meters are shown on the left and two pH meters are shown at the right side of the picture

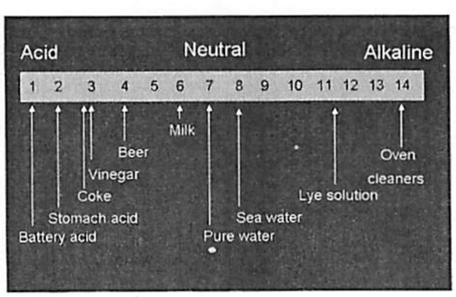

Figure 2. The pH of some common liquids found around the house. Note that both liquids with very low and very high pH are extremely reactive and can be dangerous. A pH of 7 (pure water) is considered to be neutral.

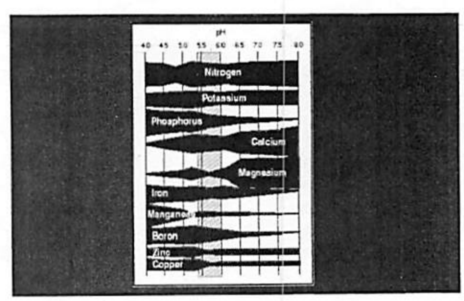

Figure 3. The availability of nutrients is affected by the pH of the growing medium. The wider a bar is, the more available that particular nutrient is. Manganese and iron toxicity are common when the pH of the growing medium is too low, while a lack of boron, iron, and manganese often causes deficiency symptoms at high pH.

1 milliSiemens = 1 mS = 1 mS/cm = 1 mMho = 1 mMho/cm = 1 dS/m = 1,000 µS (microSiemens) = 1,000 µS/cm. Some meters will measure conductivity in units of ppm and the conversion of ppm to mMho can be tricky, since it depends on the exact meter you are using. Conversion factors to change ppm measurements to mMhos vary from 640 to 700 ppm per mMho. Since most recommendations for the fertilizer status of growing media are based on mMhos and not on ppm, we recommend that you get a meter that measures conductivity in mMho. The instrument should have a range of at least 0 to 8 mMho.

CALIBRATION. When using pH and EC meters, it is absolutely crucial to calibrate them every time you use them. Unfortunately, there still seem to be a lot of people who try to save some time by not calibrating their meters. For those of us, who do not calibrate our meters to save some time, there is some excellent news! You can save even more time by not collecting and measuring any samples either!

Think about it, if you don't calibrate your meter, it will not give you accurate values. You will get the wrong information about what is happening with your fertilizer solution or growing medium. If you use the wrong information, you surely will make the wrong decisions about your fertilizer program. So if you don't calibrate your meters, you are probably better off not taking any measurements either.

Calibration solutions for pH and EC meters are available in bottles and single-use pouches. You also can buy capsules to mix up your own calibration solutions for pH. If you buy your calibration solutions in bottles, don't calibrate your meter by inserting it into that bottle. Instead pour just enough of the solution into a clean plastic or glass container and use that solution to calibrate your meters. This minimizes the possibility of contaminating or spilling all of the calibration solution. It also is important that you don't use the same calibration solution for too long, since it may get dilute or contaminated. Replace the calibration solutions with fresh solution at least once a month.

pH meters should first be calibrated with a solution of pH 7 and then with a solution of pH 4. Make sure to rinse the pH meter with distilled water before placing it in the pH 4 solution to prevent contaminating the solution. Most of the basic pH meters will have two little calibration screws that you will need to adjust to calibrate the meter, while some of the more expensive meters can calibrate themselves when they are placed in the appropriate solutions. Proper storage of pH meters also is very important. Most meters have a glass bulb, which contains the actual sensors. If this bulb dries out, the meter will no longer work. To prevent this, pH meters should be stored with a little bit of pH 7 solution in the cap that protects the sensor.

Only one calibration solution is needed for EC meters, normally either 1.413 or 2.764 mMho. Just like with pH meters, calibration normally is doing by adjusting a little setscrew. Storage of EC meters is easier than that of pH meters. EC meters should be stored dry and clean.

Test your fertilizer solution.

By far the easiest thing to measure in your greenhouse, are the EC and pH of your fertilizer solution. Of these two measurements, the EC is much more important, because you can use it to calculate the concentration of your fertilizer solution. I realize that most of you probably don't like math a whole lot, but the calculations are fairly simply, and should take less than a minute. Before you do the calculations, you need to do three things:

- ◆ measure the EC of your irrigation water (without any fertilizer in it!). Keep in mind that this can change throughout the year, especially if you live somewhere with pronounced wet and dry seasons. Thus, measure it every time you want to determine the fertilizer concentration.

- ◆ measure the EC of the fertilizer solution. Make sure that the stock solution is mixed well. To get a representative sample, we recommend that you collect some solution in different places in your greenhouse (as long as they are all supplied by the same injector) or at different times (a minute or so apart).

- ◆ find out what the EC of a 100 ppm nitrogen solution of your fertilizer is. If you are using a pre-mixed, water-soluble fertilizer, this information should be available on the back of the fertilizer bag. If not, contact your supplier or company representative to get this information. Keep in mind that this value gives the EC of a 100 ppm nitrogen solution, assuming that there are no soluble salts at all in your water source.

Now, you're ready to calculate the concentration of your fertilizer solution in a few simple steps.

1. Subtract the EC of the irrigation water from the EC of the fertilizer solution. This will tell you how much the fertilizer contributes to the total EC of the fertilizer solution.

2. Divide this value by the EC of a 100 ppm N nitrogen solution.

3. Now multiply this number by 100 and you have the nitrogen concentration of your fertilizer solution (in ppm of nitrogen).

Here is an example: You measure the EC of your irrigation water and it is 0.45 mMho. The EC of the fertilizer solution is 2.1 mMho and the fertilizer bag shows that a 100 ppm solution has an EC of 0.60 mMho.

Step 1 of the calculations tells a us that the fertilizer contributes 2.1 -0.45 = 1.65 mMho to the EC of the fertilizer solution. We now divide this value by the EC of the 100 ppm solution and get 2.75 (1.65/0.6 = 2.75). Therefore, the concentration of the fertilizer solution is 100 x 2.75 = 275 ppm nitrogen.

You can do a very similar calculation to determine what the EC of your fertilizer solution should be at a particular fertilizer concentration. For help with these and other fertilizer calculations, you can download a spreadsheet (in Excel format) from my website at www.uga.edu/~hort/FacMWVI.html.

You can also use your EC meter to test whether your fertilizer injector is working properly. To do this, you need to know the injection ratio of your injector. On some injectors, you can read off the injection ratio directly from the injector, while on others you may need to do some calculations. For example, some injectors will show a dilution percentage instead of an injection ratio. If you know the dilution percentage, you can easily calculate the injection ratio: injection ratio = 100 divided by the dilution percentage. For example, a dilution percentage of 1 is the same as an injection ratio of 100 (100/1 = 100), while a dilution percentage of 0.5 is the same as an injection ratio of 200 (100/0.5).

Now that you know the injection ratio, start the irrigation system, whether it is a watering hose, drip system, or overhead irrigation system. Make sure that your fertilizer stock solution is mixed well, as you do this. Collect a sample of the fertilizer solution and measure the EC of this solution. Also collect a sample from the stock solution and dilute this according to the injection ratio of the fertilizer injector (i.e., if you have a injection ratio of 200, you need to dilute the sample from the stock solution 200 times). Be sure to use the same water source for this dilution as what you use for irrigation!

The fertilizer solution sample from the irrigation system should have the same EC as the sample from the stock solution that you diluted yourself. If you find a large difference, repeat the test several times to make sure that you didn't make a mistake. If you still find a difference, your fertilizer injector is not working properly and may need maintenance or repairs. Also make sure that the injector is installed properly. It is easy to hook an injector up backwards, and they will not work correctly when this happens.

You can use an in-line EC meter to monitor the EC of your fertilizer solution (Figure 5), which makes it even easier to make sure that your injector is working properly. If your fertilizer injector malfunctions, or you have mixed up the wrong concentration of stock solution, this will be reflected in the reading of the EC meter. Using an in-line EC meter is a very simple and effective way to make sure that your injector is working properly.

Test the growing medium.

The most important characteristics of the growing medium are the pH and EC and both can be measured quickly in the greenhouse, using a simple test. The pour-through method was developed for this specific purpose and is based on the idea of extracting some of the solution from the growing medium, which can then be analyzed. It is important that the pots are watered thoroughly before collecting the leachate, and the leachate should be collected about two hours after the last irrigation.

The pour-through method is very simple. First, place a pot or cell pack in a saucer. It is best to elevate the pot or cell pack slightly, for example by placing it on top of a ring cut from a PVC pipe. Then pour just enough water on top of the growing medium in the pot to leach some of the solution out of the bottom. If your irrigation water is high in alkalinity (more than 100 ppm), you should use distilled water instead. Don't use more water than is needed to get enough leachate for the EC and pH measurements. How much leachate is needed, depends on the type of EC and pH meter you are using. After you collect the leachate, you can measure the pH and EC, either by pouring the solution into the meter (for example with the agri-meter), or by pouring the solution in a small cup or beaker and placing the meters in the solution. Leachate from at least five different pots should be collected to get representative samples.

The pH of the leachate should be between 5.4 and 6.0 for most crops. Some exceptions include Easter lily, which prefers a pH of 6.4 - 6.8, and azalea and blue hydrangea, which need a pH below 5.6. As long as the pH is within the recommended range, and you are using a fertilizer which includes the necessary micronutrients, it is unlikely that you will have problems with micronutrient deficiencies or toxicities.

The leachate EC is a measure of the total amount of soluble salts in the growing medium and should be between 2.0 to 3.5 mMho or most crops. Heavy feeders, such as poinsettia and chrysanthemum prefer a higher EC (2.5 to 4.6 mMho), while salt-sensitive plants prefer an EC between 1 and 2.6 mMho. The optimal leachate EC also depends on the quality of your irrigation water. If the EC of the irrigation water (without any fertilizer in it) is high (more than 1 mMho; this may be the case if you have hard water), you should try to keep the leachate EC in the upper part of the recommended range, while the lower part of these recommended EC ranges will be better if you have soft irrigation water.

Growing plants with too little fertilizer will slow down the growth of the crop and result in a longer growing period for the plants. There also may be signs of nutrient deficiencies, and the exact symptoms will depend on which nutrient is most deficient. Applying too much fertilizer to a crop may not result in any visible symptoms, although salt-sensitive species are likely to show burn symptoms on the edges of the leaves. Symptoms of high fertilizer levels often will appear mainly in the roots of the plants. It can result in subtle damage to the roots, making them more susceptible to root diseases. Another common problem with overfertilization, especially in combination with ample amounts of water, is poor root growth. Large root systems will develop only if the roots have to explore the growing medium in the pot for water and fertilizer. If both are present in excess, a small root system will be able to supply the above-ground part of the plant with all the required water and nutrients. This will result in healthy-looking shoots, with small roots systems. This makes the plants susceptible to falling over and they will perform poorly after they are transplanted into the landscape.

Since both too much and too little fertilizer will result in low-quality plants, it is important to keep the EC of the growing medium within the recommended range. If the growing medium EC is not within the optimal range, test your fertilizer solution to make sure that you are actually applying the same amount of fertilizer that you think you're applying. When you know the concentration of your fertilizer solution, you can decide whether to increase or decrease it, and by how much.

Keep in mind that measuring the EC with the pour-through method only determines the TOTAL amount of soluble salts, but gives no information about the presence or absence of individual nutrients. Thus, it is possible that a particular nutrient may not be present in sufficient amounts, even if the EC is within the recommended range.

If you are using a well-balanced fertilizer, this will probably not be a problem, but if you want to be certain, you can send a sample of the growing medium to a soil testing laboratory. Most land-grant universities have this service, and there also are several private labs that can analyze your samples. When you prepare soil samples for a soil testing lab, remove the upper 1/2 to 1 inch of the growing medium and then collect a core of the growing medium from the top to the bottom of the pot.

Soil testing labs generally use the 1:2 dilution method or the saturated medium extract (SME) method. Although you don't need to know exactly how these labs prepare the samples, it is important to realize that their preparation methods include dilution of the samples. Because of this, the EC results from a soil testing lab will always be lower than the EC you measure in your greenhouse with the pour-through method, and the results should be interpreted accordingly (see Table 1). These labs will also measure the pH of the growing medium, and perhaps most importantly, they can measure the concentrations of individual nutrients in the growing medium. Some soil testing labs also have guidelines of what the concentrations of these individual nutrients should be, so they may be able to tell you which, if any, of the nutrients are present in insufficient or excess amounts. This information can be used to adjust the fertilizer program when you need to apply more or less of specific nutrients.

Test the plant tissue.

Leaf tissue analysis is a very reliable method to make sure that your plants contain all nutrients in sufficient amounts. Unfortunately, these tests cannot be done in a greenhouse, so samples need to be sent to an analytical lab. Normally, full-grown leaves from the top of the plants should be collected for analysis. If an overhead irrigation system is used to apply water-soluble fertilizer, the leaves should be rinsed off gently and blotted dry before they are mailed to a lab. This assures that any fertilizer residue is washed from the leaf surface. Do not sample leaves from diseased or wilted plants. These leaves are likely to suffer from other problems and they will confound the tissue analysis data. Different labs may require different amounts of leaf tissue for analysis, so check with your lab on how much leaf tissue you should send.

Analytical labs can analyze the leaf tissue for the concentrations of all essential nutrients. This information is especially useful when you have a crop that does not grow well. The results from the analysis will indicate which nutrients are deficient, which will allow you to make changes in your fertilizer program to solve these problems. Keep in mind that micronutrient deficiencies are most likely caused by the pH of the growing medium, which may be too low or too high. When this is the case, extra applications of micronutrients are unlikely to solve the problem. Instead, the pH of the growing medium should be altered. Therefore, when you're trying to identify a nutritional problem in a crop, you should make sure to get analyses of both the leaf tissue and the growing medium. The combination of these two analyses should be enough to identify any nutritional problem your crop may have. Some general guidelines for leaf nutrient concentrations are shown in Table 2. Keep in mind that these values may not be suitable for every crop you grow, since different species and cultivars may have different nutrient requirements. For help with interpretation of leaf tissue and growing medium analyses, you should contact your extension service.

Leaf tissue analysis is not only useful when you have problems with a crop, but also can be very valuable when you have a good-looking crop. It may tell you whether some of the nutrient are close too deficiency or excess levels, allowing to you to fine-tune your fertilizer program. More importantly, if you get a problem-free crop analyzed, you can use that information as a benchmark for comparison of future crops. Because of the large number of floricultural crops and cultivars, we do not have good guidelines for optimal nutrient concentrations of all crops. So, if you can gather this information for the most important crops in your own greenhouse, you can develop some of your own guidelines.

Some closing remarks.

Some people find the investment in an EC and pH meter too high, because they feel that they can't afford to spend $150 to help detect problems that they may not even have. The flip side of that argument is that you need to ask yourself whether you really can afford not to spend this money. Nutritional problems are very common in greenhouses, and most of them can be prevented by regular monitoring of growing medium EC and pH. How much does it cost you when you have a serious nutritional problem in your crop? In the best case scenario, you may have to keep the crop in your greenhouse for a few more weeks, so you can correct the problem, while in the worst case you may end up throwing away a few thousand flats or pots. How does the cost of these problems compare to the investment in an EC and pH meter that can help to prevent these problems? I'll leave the math up to you, but I think I know what your conclusion will be.....

The bottom line is that routine monitoring of growing medium EC and pH can be a great help in preventing serious nutritional problems in your crops. Occasional analysis of the growing medium and leaf tissue by a soil testing lab can help you fine-tune your fertilizer program and will provide valuable information when you have a fertilizer-related problem in your greenhouse. It is the most-reliable method to find out if your plants actually get all the nutrients they need.

Remember, practically all nutritional problems in greenhouses can be prevented if you pay close attention to your fertilizer program and set up a schedule to take the necessary measurements to monitor the nutritional status of your crop. As a grower, it is your responsibility to make sure that your plants are on a healthy diet!

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Table 1. Comparison of EC values measured with different methods. Since the results of EC measurements vary greatly among different methods, it is crucial that you know which method was used to measure the EC of your samples. Make sure that you use the guidelines that were developed for your specific testing procedure.

Indication	1:2	SME	PourThrough
Very low	0 - 0.3	0 - 0.8	0 - 1.0
Low	0.3 - 0.8	0.8 - 2.0	1.0 - 2.6
Normal	0.8 - 1.3	2.0 - 3.5	2.6 - 4.6
High	1.3 - 1.8	3.5 - 5.0	4.6 - 6.5
Very high	1.8 - 2.3	5.0 - 6.0	6.6 - 7.8
Extremely high	more than 2.3	more than 6.0	more than 7.8

Table 2. Optimal fertilizer concentrations for the leaf tissue of many greenhouse crops. Although most crops grow well when tissue nutrient concentrations are within these ranges, it is important to realize that different species and cultivars may have different nutrient requirements. Therefore, the values in this table should be considered as rough guidelines, which may not be appropriate for all crops.

Macronutrients (%)

N	P	K	Ca	Mg	S
2.5 - 4	0.4 - 1	2.5 - 4	1 - 2.5	0.25 - 1	0.2 - 0.7

Micronutrients (ppm)

Fe	Mn	B	Cu	Zn	Mo
50 - 120	50 - 300	25 - 75	5 - 25	25 - 100	0.2 1