EC AND pH: WHAT IS IT AND WHY DOES IT MATTER?

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Nutritional problems are very common in greenhouses and may go undetected for prolonged periods. Over- or underfertilization will normally result in reduced plant vigor, which may make the plants more susceptible to diseases and insects. There are many good water-soluble fertilizers available and in recent years, improved guidelines for fertilization programs have been developed. It is now possible for growers to test the growing medium throughout the production cycle. Because these measurements can be taken in the greenhouse, it allows growers to make immediate adjustments to their fertilization practices. The two most important measurements that can be collected are pH and EC (electrical conductivity) of the growing medium. Regular monitoring of growing medium EC and pH will eliminate almost all problems associated with fertilization. The importance of pH and EC, as well as a method to measure them, are outlined here.

pH (ACIDITY OR BASICITY). pH is a measure of how acid or basic the growing medium is. pH is expressed on a scale from 0 to 14, where 0 - 7 is the acid range and 7-14 is the basic range. A pH of 7 is considered to be neutral. From a scientific point of view, pH is a measure of the amount of hydrogen ions that are present in a solution. This has little practical relevance form a plant nutritional point of view, since hydrogen is not a plant nutrient.

pH is important, because it affects the availability of micronutrients in the growing medium (see Fig. 1). At a high pH, some nutrients that are essential for good plant growth become unavailable and the plants will start developing deficiency symptoms. Iron deficiency is probably the most common problem that occurs when the pH of the growing medium is higher than optimal. Iron deficiency symptoms include yellowing of the leaves, especially in between the veins, and normally occur in the younger leaves of the plants. Since many micronutrients cannot be redistributed within plants, symptoms can appear quickly if the pH of the growing medium is not within the optimal range.

Almost all crops prefer a slightly acidic pH and grow well if the pH is between 5.4 and 6.0. However, some crops prefer a slightly higher or lower pH. Recommended pH for a variety of crops is indicated in Fig. 2.

Water quality and pH. Ideally, the pH of irrigation water should be between 5.2 and 6.8. However, the quality of irrigation water not only depends on the pH, but also on the alkalinity of the water. Using irrigation water with high alkalinity (high $CaCO_3$) often result in an increase in the pH of the growing medium, and can cause micronutrient deficiencies. Analytical results for alkalinity can be confusing, because it can be expressed as ppm, mg/L, or meq/L and it can be expressed as $CaCO_3$ or HCO_3^-. To convert these different measures, use the following numbers: 50 ppm $CaCO_3$ = 50 mg/L $CaCO_3$ = 1 meq/L $CaCO_3$ = 61 ppm HCO_3^- = 61 mg/L HCO_3^- = 1 meq HCO_3^-. Generally, irrigation water with an alkalinity of less than 100 ppm is of good enough quality for greenhouse use. If alkalinity is higher than 150 ppm, it normally has to be acidified before greenhouse use. Acidification can be achieved by injecting an acid (most commonly sulfuric, phosphoric, nitric, or citric acid) into the irrigation water. This will reduce the total alkalinity of the water by removing part of the carbonates and bicarbonates in the water. The exact amount of acid that needs to be added to the water depends both on the pH and the alkalinity of the water. Water with high alkalinity will often need more acid than water with low alkalinity, even if the initial pH of the water is lower (see Fig. 3 for an example). The NC State floriculture web site contains a program to calculate how much acid is needed to neutralize irrigation water, depending on the pH and alkalinity of the water (http://www.ces.ncsu.edu/depts/hort/floriculture/programs/alk.html).

Controlling pH. Several measures can be taken to decrease the pH in the growing medium. In cases of irrigation water with a high pH and/or alkalinity, it is useful to acidify the water to a pH of approximately 5.8. Switching from high nitrate to high ammonium fertilizers will also help to reduce the pH. Make sure that your

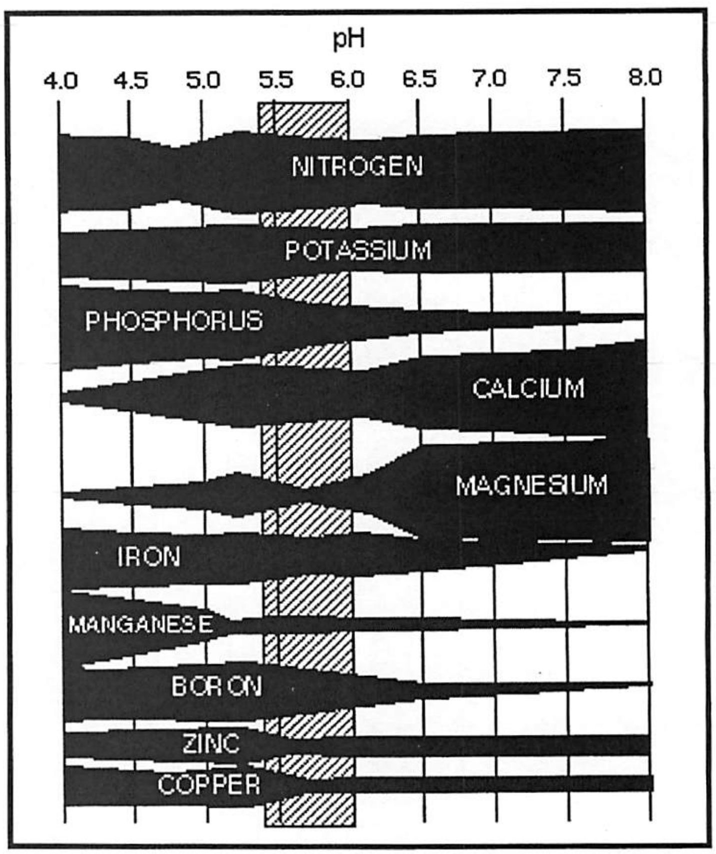
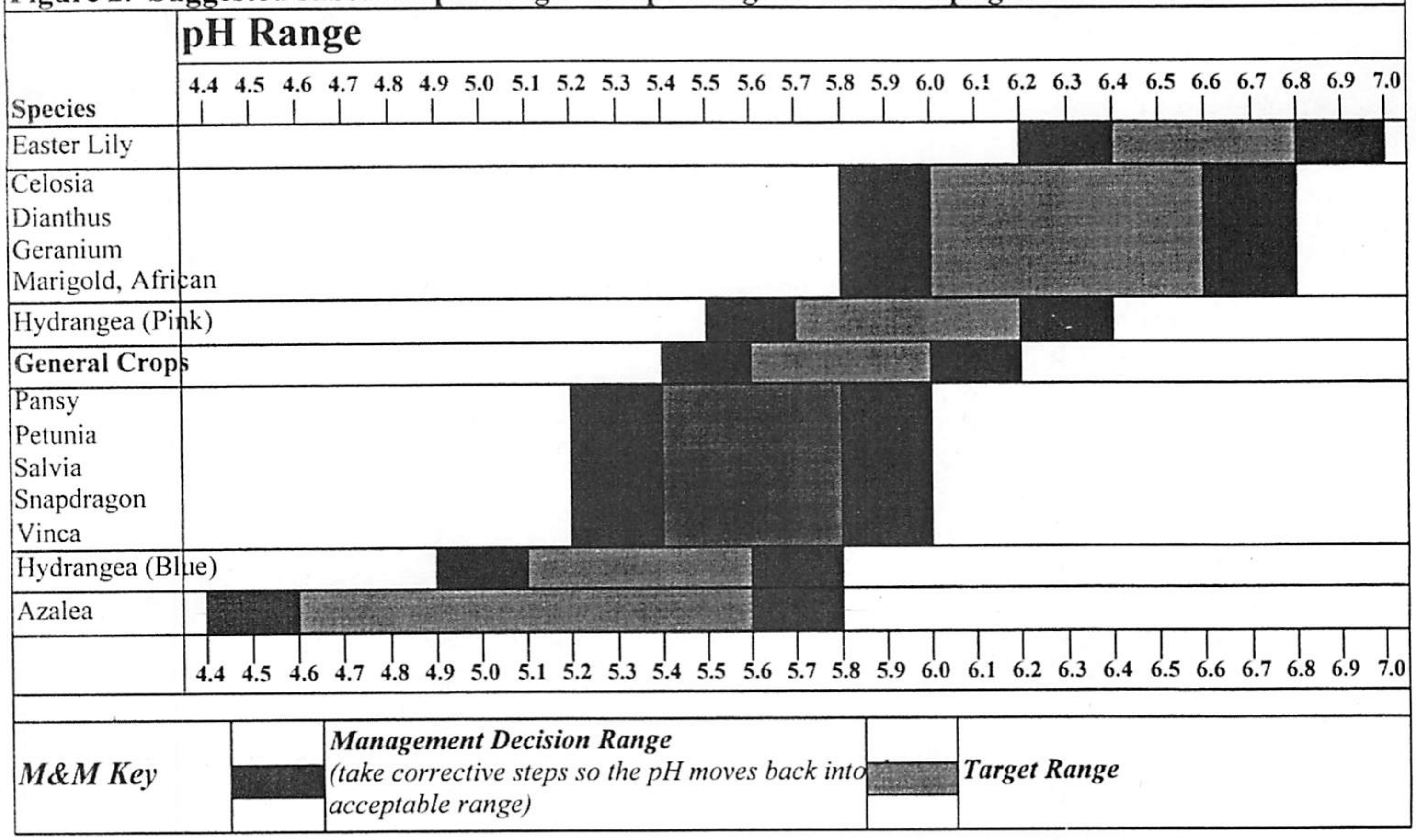


Figure 1. Influence of pH on the availability of essential nutrients in a soilless substrate containing sphagnum peat moss, composted pine bark, vermiculite, and sand. The pH range recommended for most greenhouse crops is indicated by slashed lines.

Figure 2. Suggested substrate pH ranges for specific greenhouse crops grown in soilless substrate.



crop is not overly sensitive to high ammonium levels! To reduce growing medium pH fairly rapidly, an iron sulfate drench can be applied at 2 - 3 lbs/100 gallons. Make sure to mist the remaining solution off the foliage following this drench. Otherwise, phytotoxicity may occur. If the above measures do not result in a large enough decrease in pH, the irrigation water can be further acidified to a pH of 5.1. If problems with a high pH are common, it may be possible to prevent future problems by reducing the lime charge in the growing medium, avoiding high nitrate fertilizers, and/or continuously acidifying the irrigation water to reduce alkalinity.

Low growing medium pH can be corrected by stopping or reducing acidification of the irrigation water, the use of high nitrate fertilizers, or drenching with flowable limestone. If limestone is used, make sure to mist the solution of the foliage following the application. If problems with low pH are common, it may be possible to avoid these by avoiding fertilizers high in ammonium, increasing the lime charge in the growing medium, or by injecting potassium bicarbonate into the irrigation water. This will increase the alkalinity of the water (13.4 oz/1000 gallons will increase alkalinity by 1 meq/L).

EC (ELECTRICAL CONDUCTIVITY). Electrical conductivity (EC) is a measure of the total amount of salts, including fertilizer salts, in the growing medium. Since the vast majority of salts in fertilizer are macronutrients, EC can be used as an indicator of the presence of macronutrients in the growing medium, but gives little or no information about the presence of micronutrients. Most crops prefer a growing medium EC of 2 to 3.5 mS/cm (1 mS/cm = 1 mmho/cm = 1 dS/m = 1000 μS/cm). Preferred growing medium EC for salt-sensitive plants is 1 to 2.6 mS/cm, while heavy feeders, such as chrysanthemum and poinsettia, prefer an EC between 2.6 and 4.6 mS/cm. Keep in mind that these EC-values are based on the PourThru method. To convert values obtained by this method to EC values determined with the SME or 1:2 dilution method, use Figure 4.

Water quality and EC. Water quality affects the interpretation of growing medium EC values, because salts from the irrigation water can accumulate in the growing medium. To adjust for this, measure the EC of the irrigation water (without any fertilizer in it!) and subtract this from the EC of the growing medium, as measured by the PourThru method. If the EC of the irrigation water is high (more than 1 mS/cm), keep the corrected EC (growing medium EC - irrigation water EC) in the lower part of the recommended EC range to reduce chances of salt-damage.

Controlling EC. If the EC is higher than desired it can be reduced by decreasing the frequency of fertilization, decreasing the fertilizer concentration, or leaching. Leaching will result in the fastest decrease in EC and should be used when the EC of the growing medium is much too high and needs to be reduced quickly to prevent crop damage. Keep in mind that a high EC normally is the result of too much fertilization. With the current focus on reducing runoff from greenhouses, it is wise to prevent problems with high EC by only applying the needed amount of fertilizer. Regular leaching is normally not necessary in a well-managed fertilizer program!
When the EC of the growing medium is too low, it can be increased by reducing or eliminating leaching, increasing the fertilization frequency, or increasing the fertilizer concentration.

MEASURING pH AND EC. There are many different ways to prepare samples for measuring EC and pH. Although results for pH measurements are similar for the different techniques, results for EC are greatly dependent on which method is used. The most common techniques are the saturated medium extraction method (SME), the PourThru method, and various dilution techniques. The PourThru method rapidly is gaining popularity, because it is the only method that can be performed by the grower in the greenhouse, it gives immediate results, it is simple, and it is cheap. For less than $150, a grower can buy all that is needed (pH meter, EC meter, and calibration solutions) to measure pH and EC with the PourThru method.

The idea behind the PourThru method is to collect some of the solution in the growing medium. This is done by first irrigating the crop to container capacity. About two hours later, water is poured on top of the growing medium and the first 50 mL (2 oz) of leachate is collected and used for analysis. The amount of water that has to be poured into the pots ranges from approximately 50 mL for bedding plant flats to 250 mL for mums in 6" pots. It is best to use the least amount of water that will still allow you

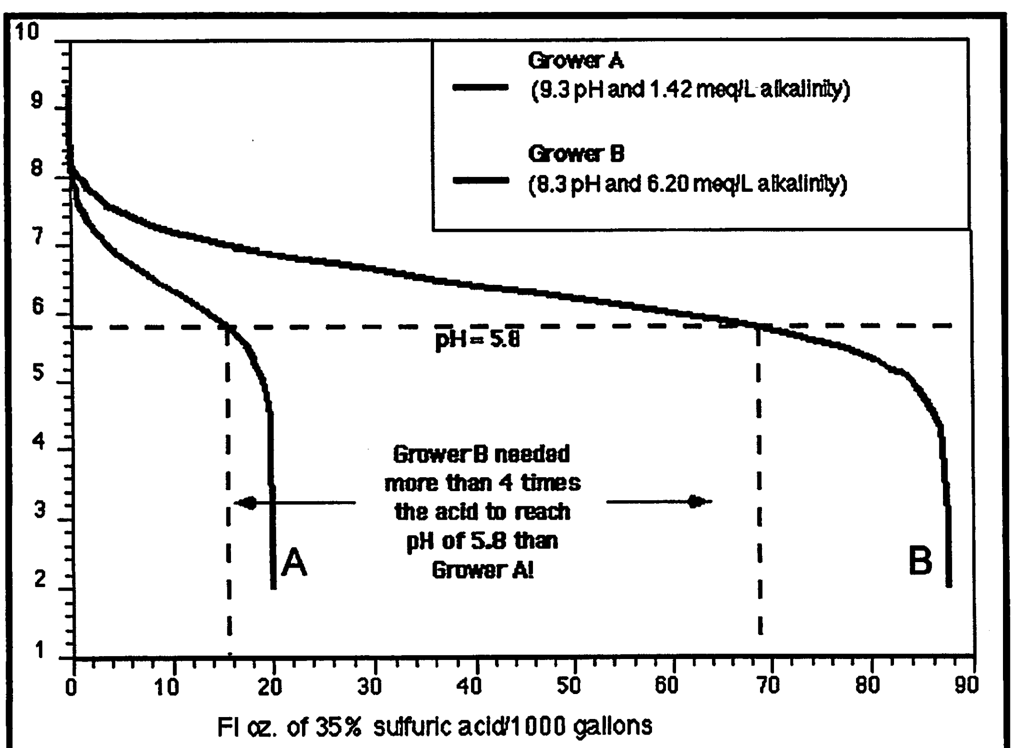


Figure 3. Titrations of two different waters with sulfuric acid. Notice that although the beginning pH of Grower A water is a full unit higher than Grower B water, it takes more than 4 times the acid (68.6 fl oz compared to 15.8 fl oz for Grower A water) to drop Grower B water to pH 5.8, due to the greater alkalinity in Grower B water.

to collect 50 mL of leachate. The pH and EC of this leachate can then be measured. If it is not possible to measure the samples immediately after they are collected, they can be stored in a refrigerator for several hours.

Water quality sometimes can affect the measurements, especially pH. Thus, water with high alkalinity (more than 150 ppm) should not be used for the PourThru method. Instead, use distilled water. It is important that the pots are watered thoroughly before collecting the leachate, otherwise, the water that is poured on top of the growing medium, may simply run through the pot. In that case you would be measuring the pH and EC of the water you poured on the pots, instead of the pH and EC of the growing medium. If automatic watering is too variable and may not saturate the pots, water the pots that you will use for the PourThru method by hand. Measure at least five pots or cell packs and use the average EC and pH of these five measurements to determine if corrective action is needed. If some of the samples yield results very different from the others, discard those results and sample again. Sample plants should be collected from the interior of the bench, since plants at the edge of the bench dry out faster and may behave a bit different from those in the interior. Make sure not to select only the best or worst looking plants, but randomly pick the samples from the bench. Otherwise, you will not get EC and pH data that are representative for the whole crop.

Bedding plants and other short-term crops should be sampled weekly, while long-term crops may be measured every other week. If some corrective action is taken, measure pH and EC more often, to determine if the steps have the desired effects.

SUMMARY. Regular monitoring of EC and pH of the growing medium can prevent almost all nutrient-related problems with the crop. Regular monitoring will give an indication of the availability of macro- and micronutrients to the crop. Currently, most growers do not have a proactive plan to prevent nutrient problems. Instead they respond to nutritional problems as they appear. At this stage it may be impossible to undo the damage that has already occurred. The PourThru method makes it possible to prevent these problems and to keep plants in optimal health. Strong plants not only are esthetically more pleasing, but also generally are more resistant to insect pests and diseases.

Keeping track of pH and EC of the growing medium should be thought of as a preventative approach to minimize nutritional problems in greenhouses. It allows for the detection of possible problems before they have an important effect on plant growth and quality. Although incorporating the PourThru method into the regular greenhouse fertilization program involves some additional work, it will be beneficial in the long run because of improved crop health. Growers who are interested in using this approach to fertilization management may want to start gradually, by monitoring only a few of the crops in the greenhouse. This will allow growers to become familiar with this new strategy, and the program can be expanded gradually over time.

1:2	SME	PourThru	Indication
0 to 0.3	0 to 0.8	0 to 1.0	Very Low
0.3 to 0.8	0.8 to 2.0	1.0 to 2.6	Low
0.8 to 1.3	2.0 to 3.5	2.6 to 4.6	Normal
1.3 to 1.8	3.5 to 5.0	4.6 to 6.5	High
1.8 to 2.3	5.0 to 6.0	6.6 to 7.8	Very High
> 2.3	> 6.0	> 7.8	Extreme

Fig. 4. Comparison of EC measured with different methods. There are large differences in the measured EC, depending on which method is used.

Some of the information for this article was compiled by the floriculture team at North Carolina State University. More information on the PourThru method and its use can be found in their extension publications and on the NC State Floriculture website: http://www.ces.ncsu.edu/depts/hort/floriculture/