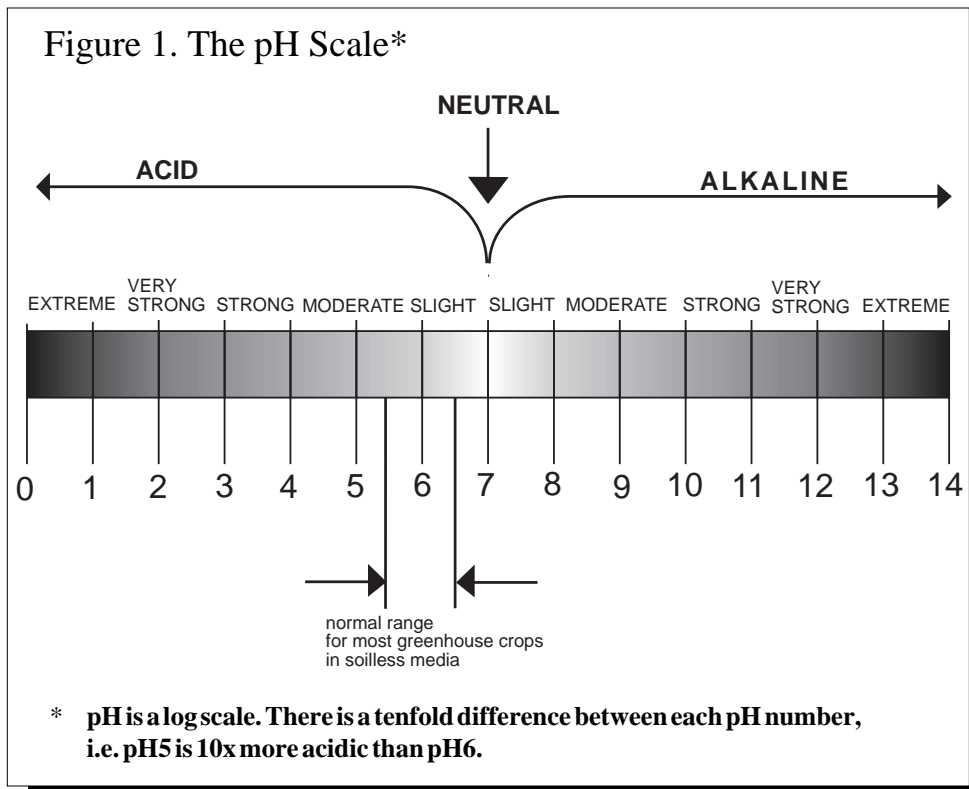


On-site Testing of Growing Media and Irrigation Water

Nutritional problems are a primary cause of economic losses associated with poor crop quality and yield. Two of the most important indicators of nutrient availability and water quality are pH and total soluble salts. These are easily monitored under greenhouse conditions. With routine testing of salts and pH, and occasional complete laboratory analyses, it is possible to eliminate almost all nutritional problems associated with the production of potted and cut flowers.

pH

The pH of the growing medium and the irrigation source can affect the availability of nutrients in solution, and the health of root systems. Most plants have a relatively narrow range of preferred pH levels. Figure 1 shows the pH scale and the preferred range (5.5 - 6.5) for most greenhouse crops grown in organic substrates. Acid tolerant crops, such as azaleas, are usually grown at pH 5.0 - 5.5. Some crops are tolerant of a wide range of pH values, while others, such as geraniums require a relatively narrow range (pH 5.8 - 6.2). Although pH can be measured by chemical titration and with the use of color indicating litmus papers, an electronic pH meter provides the most accurate and practical means of on-site testing.



pH Meters

Portable pH meters suitable for greenhouse use range in price from about \$80 to \$1000. In general, the accuracy and longevity of the meter increases with the amount paid. Most meters use a remote semi-permeable glass electrode filled with a solution of mercury or silver chloride. In some cases the electrodes are refillable, which extends their useful life. Whenever an electrode cannot be accurately calibrated between two standard buffer ranges, there is usually a problem with the electrode, or the batteries are low. These instruments must be handled and stored carefully, and the electrode end must usually be kept immersed in a liquid according to manufacturer's directions. A new type of pH meter is now available that uses a flat electrode which does not require wet storage. Other features to look for in a pH meter are automatic temperature compensation, and auto calibration. Digital readouts are now standard in most meters. The level of accuracy needed for horticulture is to one decimal point, i.e., pH 6.2.

Electrical Conductivity (EC)

Fertilizers and other dissolved salts change the ability of a solution to conduct electricity. Pure water is not a particularly good conductor, but as the salinity level increases, its conductance also increases. Salt meters (conductivity meters) are used to measure the electrical conductivity of solutions. This provides a rough idea of the fertilizer content of the irrigation water and the media solution. One factor that must be kept in mind is that not all salts are fertilizers. Some water sources are high in non-fertilizer minerals that tend to increase the overall conductivity. So while EC measurements are a good indicator of relative fertility levels, particularly if measured regularly and tracked over time, it is important to establish the non nutritional background content of irrigation sources and to have an occasional complete mineral analysis performed by a testing laboratory to determine the balance of nutrients in the media.

EC Meters

Portable EC meters for use in horticulture range in price from about \$80 to \$1000. The more expensive meters should last many years, although the electrode sensors may need replacement periodically. There are a variety of inexpensive pen type meters that are quite accurate and convenient to use for spot checking irrigation solutions and media salts. Standard solutions are available for calibrating the meters. Some features to look for are auto calibration, auto temperature compensation, easy to read displays, and probe replaceability. EC meters usually provide a readout in millimho's (mmho) or millisiemens (mS). They are numerically identical units. Some autoranging meters may provide a readout in micromho's (mmho) or microsiemens (mS). These units are 1/1000th of a millimho or millisiemen.

Testing Methods

For irrigation water and fertilizer solutions, testing is a straightforward matter of monitoring the pH or EC directly. Follow the instructions provided with the meter and be careful to rinse the electrode surfaces after use and store the instruments properly. Buffered calibrating solutions are usually supplied with pH meters and standard salt solutions are available to check and adjust the accuracy of EC meters. These calibrations should be performed often.

Water and Nutrient Solutions

Well or tap water should be checked before fertilizers are added to determine any background levels of salinity and the initial pH. It is important to allow tap water to sit for about 60 minutes when measuring pH. This allows any carbon dioxide gas dissolved in the water to come to equilibrium with the air. Dissolved CO₂ will tend to lower pH readings. If the water shows any substantial salt content (0.5 mS or above), an irrigation water quality analysis should be performed by a testing laboratory to determine the background mineral content. The report should include the elemental content, including the level of bicarbonates. Once a background EC is known, it must then be taken into account when measuring fertilizer content with a salt meter. For instance, if

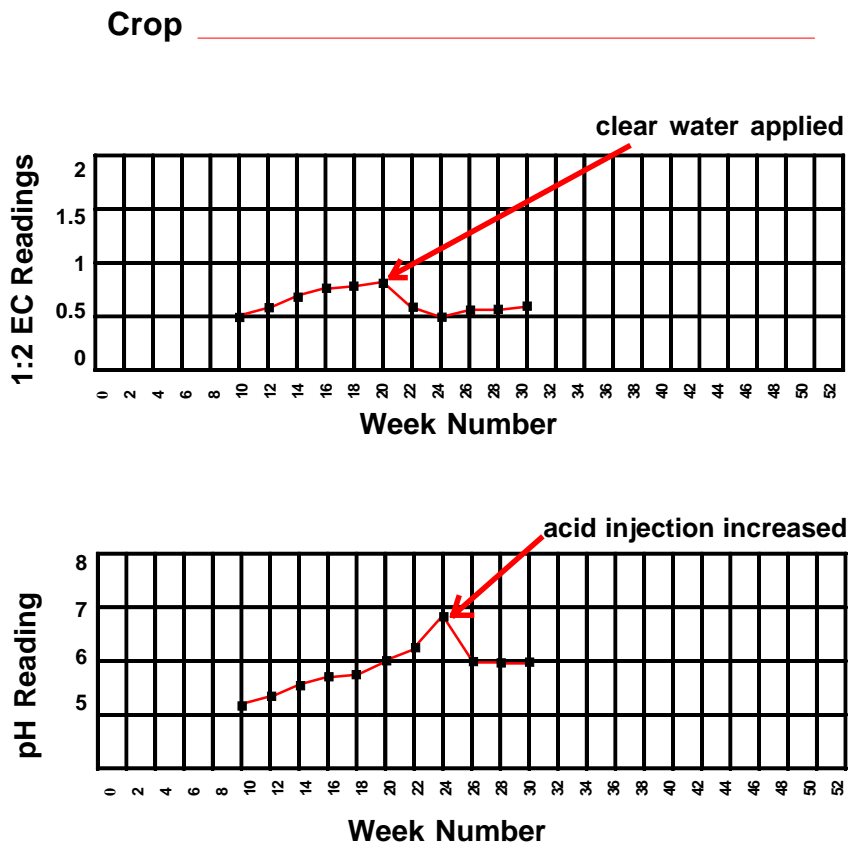
your water has an initial EC of 0.8 mS, then you will need to subtract this amount from your fertilizer solution readings to determine the actual fertilizer content of your nutrient solutions. This is important whenever you are checking the accuracy of injectors. Most commercial soluble fertilizers will indicate the EC values on the bag for various feeding concentrations. In order to check the calibration of your injectors, you must subtract the background EC levels from your measured fertilizer EC values after injection.

Media Testing Record Keeping

Growing media should be tested for salts and pH on a routine basis. Testing should begin before the crop is planted and be performed at least every two weeks. It's important to keep records so that you can chart pH and EC levels over time. (See Figure 2.) Graphically charting your pH and EC values will provide you with a trend of timely information on whether the pH and EC are rising, falling, or staying steady. This is at least as important as the actual reading. It will enable you to make informed decisions about fertilizer concentrations, watering frequencies, and leach rates. Very often, growers who use routine media testing find they can produce superior crops with less fertilizer and lower leaching rates, thereby reducing waste and the possibility of environmental contamination. Use the blank charts included on the last pages of this factsheet as photocopy masters for tracking your own crops.

Graphically charting your pH and EC values will provide you with timely information on whether the pH and EC are rising, falling, or staying steady. It will enable you to make informed decisions about fertilizer concentrations, watering frequencies, and leach rates. Use copies of the blank forms on pages 11 and 12 for tracking your own crops. If you use an extraction method other than the 1:2 you will have to rescale the EC values. You can post this information so that all staff are aware of current fertilizer conditions in the crop.

Figure 2. Tracking EC and pH Values



Collecting a Media Sample

There are two strategies available for media sampling. First, you could take several samples and measure them individually. This would provide you with a good indication of the uniformity of your watering and fertilizing program. If the results are dramatically different from pot to pot or location to location, it might provide a clue to uneven growth or other crop problems. However, collecting and measuring 10 or more separate samples and measuring them individually can be very time consuming, and may not provide information that is any more useful than a representative or average sample. In any case, it isn't practical to water and fertilize each plant individually. For these reasons the representative sample method is usually the one to use.

To obtain a representative sample it is necessary to combine several sub samples in order to obtain an average value. Depending on the size of the crop, samples from about 10 different pots or growing bed locations are usually required. Combined samples should always be from within one distinct growing unit, environment, irrigation method etc. The samples should be obtained from uniform plants that are the same type, age, and in the same size container. Try to collect your samples at the same time between irrigations, i.e., just before the next watering. Avoid sampling the top 2 cm of media since there are usually very few roots in this zone, and the salts tend to be higher due to evaporation of water from the soil surface. Collect samples from the mid-range of the pot, making sure to include more than just the soil at the outside edge of the container. You can usually remove about 10% of the media without harming the plant.

Use fresh, moistened growing media to replace the soil removed by your sample. Follow the same procedure for growing beds, by avoiding the top 2 cm and making sure that your sample is from the area of most active root growth. It is very important to be consistent in your sampling methods, so that your results will be accurate when tabulated over time. When all the sub samples have been collected, place them in a clean container or bag, and mix thoroughly taking care not to crush any controlled release fertilizer beads.

Extraction Methods

Only the media solution can be tested, and there is usually not enough of it to sufficiently immerse the EC or pH probes without adding water. Also, the EC in the growing media changes with moisture content, becoming more saline as the media dries. It is therefore necessary to add enough water to the sample to immerse the electrodes and to have comparable readings from one sampling date to another.

Over the years, several dilution and extraction methods have been devised. All have advantages and disadvantages, and all may provide different instrument readings. This often leads to confusion when trying to discuss or compare values obtained from different extraction methods. Three methods are described in this factsheet: the 1:2 extraction, the saturated media extraction (SME) and the pour-through method. Other methods such as the 1:5, and the 1:1.5 dilution methods are described briefly, although they are not as commonly used.

1:2 Media Extraction

This method is probably the fastest and easiest, and has been used for many years. Although easy to perform, it may be slightly less accurate than the saturated media extract due to differences in the amount of moisture in the media at sampling time and the degree to which the media is compressed to measure the sample. If you can be consistent in the volume and compression of your samples, and if you always sample at about the same degree of wetness, you can achieve fairly uniform results when tracking

EC over time. pH is relatively unaffected by the amount of moisture present, but to obtain greater accuracy in EC measurement using this method, you could air dry your samples for a few days before measuring. However, this defeats the purpose of a fast, on site test from which to make immediate fertilizer and watering decisions.

The 1:2 method uses 1 part soil to 2 parts distilled or deionized water. (See Figure 2.) It's important **not**

to use tap water, particularly if your water source is highly buffered or saline, as this will affect your test readings.

Equipment needed:

- ✓ 1 bucket or bag for mixing the samples
- ✓ 1 standard measure (either 50 ml, 100 ml, 1/4 cup, 1/2 cup etc.)
- ✓ 1 larger container to hold the water and soil mixture
- ✓ 1 plastic mixing spoon or spatula
- ✓ distilled or deionized water
- ✓ filter paper or sieve
- ✓ EC meter (properly calibrated)
- ✓ pH meter (properly calibrated)
- ✓ record book or recording sheets
- ✓ small beaker for sieved solution

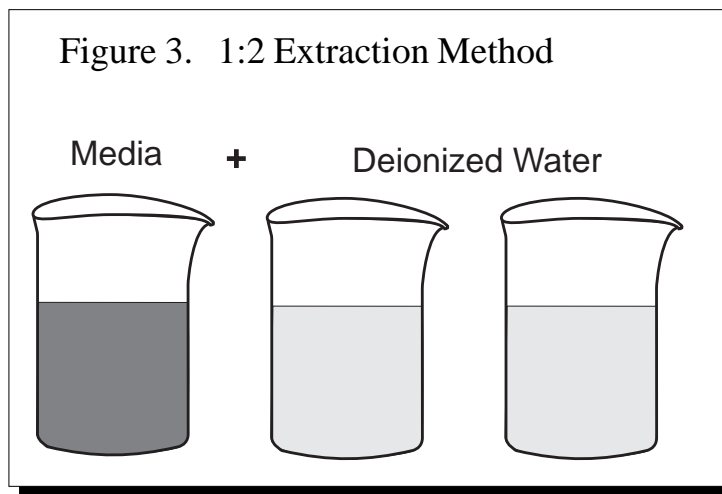
Method

1. Mix growing media subsamples thoroughly to prepare a representative sample.
2. Using the standard measure, obtain 1 level volume of media, compressing it slightly. Be sure to always use a constant pressure when packing the measure. Try to duplicate the same degree of media compaction as in the crop.

3. Empty the measured media into the large container.
4. Add 1 measure of deionized water to the large container and mix with the soil.
5. Let the mixture stand for at least 15 minutes. This is now a 1:1 soil/water mixture.
6. If the media is largely organic, take a pH reading by immersing the electrode directly into the slurry and record the reading. For mineral or sandy media, read the pH after sieving to avoid damaging the glass electrode. After removing the probe from the media rinse it according to manufacturers instructions.
7. Add another volume of water, stir, and wait 5 minutes. You now have a 1:2 soil/water mixture.
8. Sieve enough of the slurry into a clean beaker to immerse the EC probe and record the reading.

Interpretation of Results:

See Table 1 (page 8) for EC values and comparisons.



Saturated Media Extract (SME)

This method uses extracted solution from a saturated 'paste' made by wetting the sample media until it is thoroughly saturated, but with little or no free water. One advantage it has over the 1:2 method or other multiple dilution methods is that the volume of test media and the amount of moisture in the sample prior to collection are not important to the accuracy of the reading. All that is required is a sufficient amount of the representative sample to produce enough liquid for an EC reading after extraction.

Two types of extraction are possible: vacuum and squeeze. Vacuum extraction is the recommended method for all growing media and particularly for media that consists primarily of soil. Although it involves some additional cash outlay for the vacuum system, you will be able to achieve EC readings comparable to a commercial laboratory if you use this method. Carefully spread saturated samples onto a filter paper in a buchner funnel taking care to fill the entire funnel and not to leave any open areas for air to channel. Mount the funnel directly onto a erlenmeyer vacuum flask and apply a vacuum to the flask. The water in the media is drawn downward through the filter paper and into the erlenmeyer flask. Measure the EC and pH of this vacuum leachate.

Many peat based media can be direct squeezed at the saturated stage with good results. Wear rubber gloves when squeezing a sample. This prevents any salts on your skin from interfering with the accuracy of the EC reading. Some good sieving materials include fine mesh nylon stockings, heavy duty cellulose cleaning cloths, and filter bags for making jellies. Special filter bags are also available from companies supplying the new flat electrode type 'Cardy' meters. If you use an improvised filter, you must take care to thoroughly rinse and wring it out before and between readings. The mesh size should stop all but the finest particles from passing through. If desired, you can filter the extract further through a coffee filter or other funnel type filter.

Media containing controlled release resin coated fertilizers should never be squeezed, since the pellets may be broken, releasing large amounts of fertilizer into the solution and providing a false indication of fertility levels. You must also take care when preparing the saturated paste for the vacuum method not to damage any controlled release fertilizer beads.

Equipment Needed:

- ✓ clean beakers or cups for preparing the saturated extract (about 500 ml or 2 cup capacity)
- ✓ plastic spatula or spoon for mixing the media and water
- ✓ small beaker(s) for collecting and reading the extract.
- ✓ vacuum option (parts available from scientific supply houses):
 - 500 ml erlenmeyer vacuum flask(s) with side spout for vacuum attachment
 - buchner funnel(s) with multiple sieve holes
 - drilled rubber stopper for the funnel end of the buchner funnel to fit the erlenmeyer vacuum flask
 - filter paper to fit the Buchner funnel
 - vacuum pump
 - vacuum hose (about 1 meter)
- ✓ squeeze option:
 - suitable filtering mesh material or special filter bags. Note: do not use this method for media containing controlled release or resin coated fertilizers.
- ✓ EC Meter (properly calibrated)
- ✓ pH meter (properly calibrated)
- ✓ record book or recording sheets

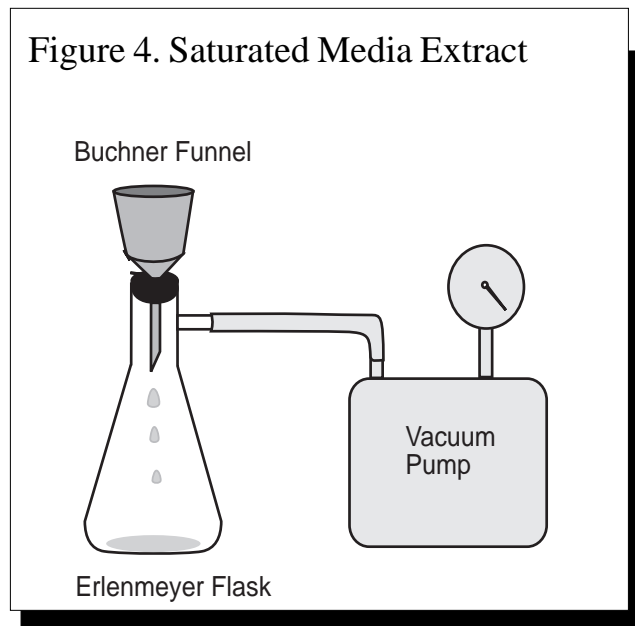
Method

1. Fill the sample container about 2/3 full with media from a blended representative sample.
2. Add distilled or deionized water slowly, while mixing with a spoon or spatula.
3. The sample is the correct consistency when the surface just glistens but there is no free water (puddles) on the surface. A small portion of the sample should remain more or less solid without dripping but should slide easily from the spoon.
4. Wait at least 15 minutes. Stir and add more water if required.
5. Read and record the pH directly from the saturated sample if the media is organic or peat based. For mineral or sandy media, record the pH after extraction to avoid damaging the electrode.
6. Extract the sample by vacuum or squeeze methods.
7. Read and record the EC.

Interpretation of

Results:

See Table 1 (page 8) for EC values and comparisons.



Pour-Through Method

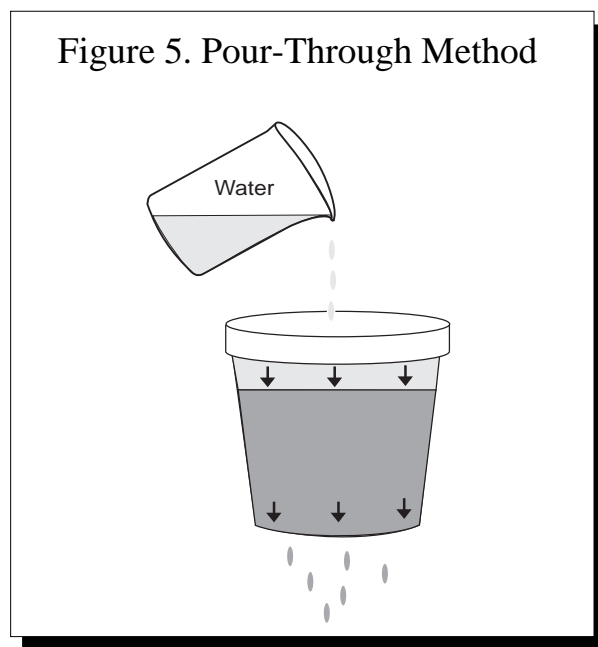
The use of resin coated controlled release fertilizers has made it necessary to investigate new methods for on-site measuring of salts and pH. Since these fertilizers tend to be quite fragile, even removing the sample from the container can result in broken beads that release all of their fertilizer salts, artificially elevating the subsequent EC readings. Many outdoor container nurseries are now using the pour-through method as a means of testing fertility. This method is quick, and can be quite accurate if sufficient care is taken to produce consistent samples. Extracts from pour-through samples can be read directly for salts and pH, or they can be combined to form a representative sample. In practice, growers often do both, since several containers must be extracted in any case.

Pour-through extraction is a two step process. First, the media is progressively wetted until just saturated and left to stand for about two hours (or the extract can be collected 2-4 hours after irrigation). Then, a volume of water sufficient to produce about 100 ml of leachate (depending on container size) is drenched onto the surface. (See Figure 4.) Care must be taken so that the water does not channel down the sides of the container. If applied carefully, the water does not immediately mix with the container solution, but evenly displaces it, driving it down into the lower root zone where some of it drains from the pot and is captured for testing. This method is still somewhat new, and standard methods are still being developed. Some

authorities suggest that pour-through readings tend to be a little higher than SME methods. Others advocate another method that involves judging when the media is at about 50% moisture capacity, and then pouring through just enough water to obtain a 50 ml sample. Until better standards are developed, it is advisable to compare your own results against the more standard 1:2 or SME methods before adopting this method.

Interpretation of Results:

See Table 1 (page 8) for EC values and comparisons.



Other Testing Methods

There are other variations on the 1:2 dilution method. A 1:1.5 method has been used in other parts of the world, and a 1:5 method was once quite common. The 1:5 method (1 part media to 5 parts water) is performed essentially the same as the 1:2 method and can be quite accurate for EC. The relative moisture of the representative samples does

not tend to skew the results as much for this method since a lot more water is added. However, since the readings are lower and in a narrower range, a well calibrated, accurate meter is needed. In addition to pH and EC measurement, new flat electrode meters have recently been introduced to test for nitrates, potassium, and sodium. (See page 9.)

Table 1. Interpreting On-Site Media Test Results.

EC reading in mS (or mmhos)

1:5	1:2	SME	Pour-Through*	Indication
0 to 0.12	0 to 0.25	0 to 0.75	0 to 0.9	Very low. Nutrient levels may not be sufficient to sustain rapid growth.
0.12 to 0.35	0.26 to 0.75	0.76 to 2.0	1 to 2.6	Low. Suitable for seedlings, bedding plants and salt sensitive plants.
0.36 to 0.65	0.76 to 1.25	2.0 to 3.5	2.7 to 4.6	Normal. Standard root zone range for most established plants. Upper range for salt sensitive plants.
0.66 to 0.89	1.26 to 1.75	3.5 to 5.0	4.7 to 6.5	High. Reduced vigor and growth may result, particularly during hot weather.
0.90 to 1.10	1.76 to 2.25	5.0 to 6.0	6.6 to 7.8	Very high. May result in salt injury due to reduced water uptake. Reduced growth rates likely. Symptoms include marginal leaf burn and wilting.
> 1.1	> 2.25	> 6.0	> 7.8	Extreme. Most crops will suffer salt injury at these levels. Immediate leaching required.

***Due to the variability of pour-through results depending upon your methods and media, you should always compare your initial results to other methods before using this technique.**

On-Site Single Nutrient Analysis

Until recently, the only way to test for individual ions was to send away samples to an analytical laboratory. Over the years, several companies have been established to meet the demand for agricultural testing, including nutrient analysis. Today, new options are emerging that make it possible to test for individual elements on-site.

Ion Specific Electrodes*



It is technically possible to monitor for many elements with ion specific electrodes. They operate in a manner similar to pH probes. These sensors can provide continuous feedback, making it possible for nutrient control equipment to perform single element dosing. This indeed is the ultimate goal of some researchers and manufacturers of nutrient control devices. However, in actual practice, most ion specific electrodes tend to be difficult to use commercially due to their tendency to need frequent re-calibration with known standards, and inaccuracies in readings caused by interference from other elements. They are also quite expensive. Until more reliable commercially useable sensors are developed, individual element dosing based on ion specific sensors will likely remain a concept for research and a few high tech inclined commercial operations.

Ion Specific Meters*



The Cardy series of meters introduced a few years ago made it possible to perform spot checks for nitrate, potassium, and sodium. These small meters use a new, flat electrode technology that does not require the electrode to be kept constantly moist. They are very accurate since they are calibrated with known standards prior to use.

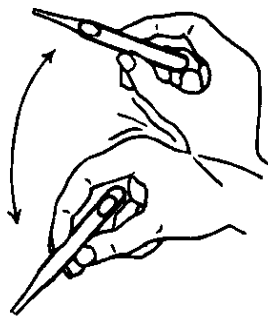
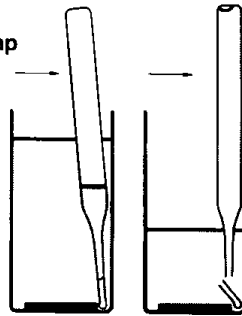
Test Kits

There are now test kits available from many companies for most of the elements of interest in horticulture. Many of these kits were not developed specifically for agricultural purposes, but for the growing environmental monitoring industry. However, their adoption for nutrient testing would appear straightforward. With these kits you can instantly test for iron, phosphate, calcium, etc. As such, they may be useful in double checking your nutrient dosing, or finding out exactly which nutrients are leaching from your property. You should be aware, however, that some tests might not provide accurate results, particularly for chelated metals. Also, interaction with other ions present in the nutrient solution may skew your results.

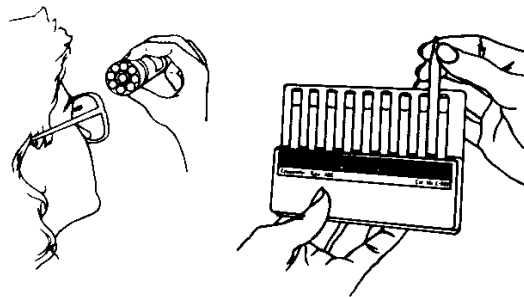
On site testing may never replace the need for laboratory analysis, but it does offer the advantage of “instant” feedback in problem solving situations. If, for instance, you think a calculation error may have resulted in ten times too much manganese addition to your stock tank, an on-site kit could tell you in a few minutes if the solution is safe to use, rather than face a disposal problem or a few days waiting for a lab test.

The CHEMets Test Procedure.*

Step 1. Fill the snap cup with the water sample, then immerse the ampoule and snap the tip. The ampoule will fill instantly and an inert bubble will form.



Step 2. Mix sample and reagent by tilting the ampoule several times.



Step 3. Quantify the result with the appropriate color comparator.

* These diagrams are provided for illustrative purposes only. No endorsement of specific products is intended.

Crop _____

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