Monitoring Electrical Conductivity in Soils and Growing Media

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Introduction

As part of the Western Forest and Conservation Nursery Association meeting this year, we held a training session on monitoring electrical conductivity (EC) in container stock. There are many new testing instruments and techniques that make monitoring quicker and easier so let's look at some of them. Note that, due to space limitations, this is a condensed version and a much more detailed article will appear in the 2006 National Nursery Proceedings.

What is EC? EC is a measure of the salinity (total salt level) of an aqueous solution. Pure, distilled water is a perfect insulator and it's only because of dissolved ions that it can conduct electricity at all (Figure 1A). An EC meter measures the electrical charge carried by the ions that are dissolved in a solution— the more concentrated the ions, the higher the reading.

In nurseries, dissolved ions come from two sources (Figure 1B). First, all irrigation water contains some salt ions as rain water trickles through the soil and rocks. The amount of the "background" salinity is a function of the local geology and climate. Soils and parent material have a major effect. Soils derived from marine sediments will contain high levels of sodium, chloride and sometimes boron. Water running through calcareous rocks or soils picks up calcium, magnesium and bicarbonate ions. Irrigation water from dry climates will have higher salinity than water from a humid climate. This only makes sense because, when water evaporates, the dissolved salts are left behind and the remaining solution would have a higher EC reading.

The second source of salinity in soils or growing media is from added fertilizers (Figure 1B). The release of salts varies considerably depending on how you are fertilizing. When fertigating, the soluble fertilizer that you inject into the irrigation water can be measured immediately. In fact, the best way to check the accuracy of your injector is to measure the EC of the applied fertigation solution. If you are incorporating controlled-release fertilizers into the soil or growing medium, however, then the salts are released according to fertilizer coating, water levels, and temperature. Most solid organic fertilizers release their nutrients very slowly and are less temperature or moisture dependent. Liquid organics release nutrients more rapidly but still much slower than soluble fertilizers.

EC Units. The physics and politics of this subject are complicated but think of it this way. We're measuring electrical conductance which is the inverse of resistance.

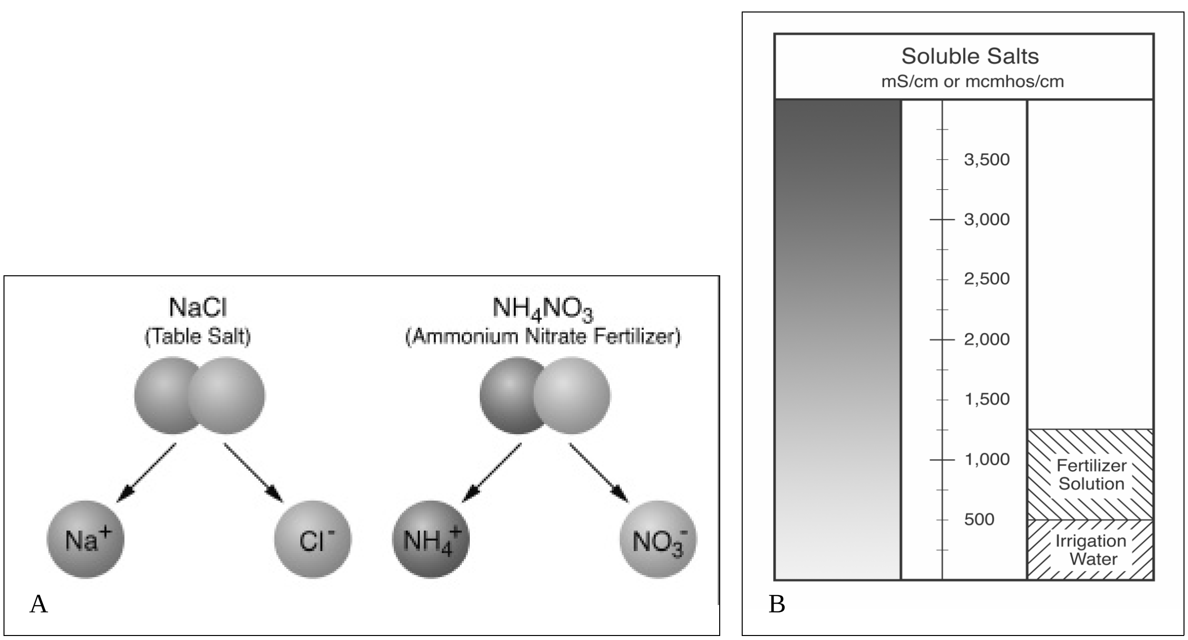

Figure 1A/B - Dissolved salts in irrigation water can be measured with electrical conductivity because they are electrically charged (A). In soil or growing media, the total salt load comes from natural sources and fertilizers (B).

The unit of resistance is an ohm, and just to be cute, they call the unit of conductance a mho (pronounced "mow"), which is ohm spelled backwards. The most commonly used EC units in horticulture are micromhos per centimeter (µhos/cm), and the SI units of microsiemens per centimeter (µS/cm) which are equivalent. Because electron activity is strongly dependent on temperature, all EC measurement must be adjusted to a standard temperature of 77 °F (25 °C).

EC Sampling Procedures

Remember that we are interested in measuring the conductivity of an aqueous solution. With irrigation water, this is simple but sampling becomes more difficult when we are measuring EC in field soil or in the growing medium inside a container. Remember also that conductivity changes with water content. With that in mind, let's look at 5 common techniques for measuring EC in nurseries. All have advantages and disadvantages, and each will give you a different EC reading. Note that we are concerned with both absolute readings, and relative changes over time.

The best EC technique will also depend on where you are using it - in bareroot soils or in containers. The EC method you choose will also depend on what size container you are sampling.

For every EC technique described below, use distilled water that you can buy at your grocery store. This prevents confounding the EC readings with background salinity of the irrigation water.

Saturated Media Extract (SME). This technique is the laboratory standard that is used by commercial soil and water testing laboratories. If you are interested in absolute EC values, this is the only choice. The SME method uses saturation as the standard soil or media water content, and hence the name. Okay, but how do you get the saturated water out of the soil or container and how do you get enough solution so that you can measure the EC?

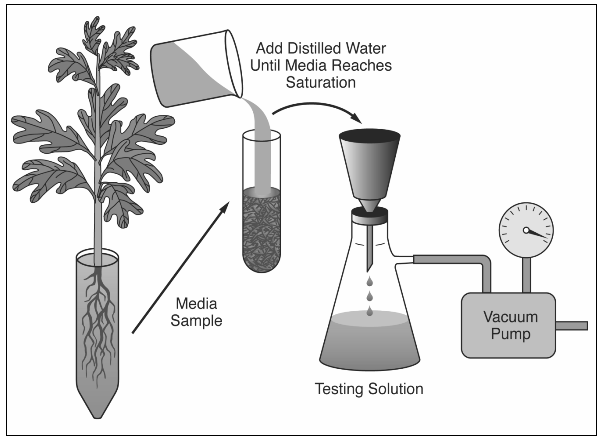

Figure 2 - The saturated media extract (SME) technique is the laboratory standard, and is the only way to obtain absolute EC readings.

The laboratory technique consists of collecting a sample and adding enough distilled water so that it just glistens. Then, a vacuum pump sucks the solution into a beaker so that it can be measured (Figure 2). A practical modification of the SME technique is to collect a sample of soil or growing medium, bring it to saturation moisture content, place it into cheesecloth, and squeeze to obtain the solution.

The SME has a major advantage over the other methods in that the amount of water is always the same, and so the moisture content of the soil or media at the time of monitoring isn't important. Of course, even if you had the necessary laboratory equipment, you probably wouldn't have the time to do this procedure every time.

Table 1— Comparison of Various Techniques of Measuring Electrical Conductivity in Nurseries

EC Technique	EC Readings (µS/cm)				Soil	Containers	Soil	CRF
Saturated Media Extract	1,000	2,000	3,000	4,000	Yes	All but miniplugs	Yes	Yes*
1:2 Dilution	300	700	1,200	1,600	Yes	All but miniplugs	Yes	No
Pour-Through	1,500	2,800	4,200	5,500	No	All but miniplugs & very large sizes	No	Yes
Plug Squeeze	1,300	2,700	4,100	5,600	No	Jiffy, Cone-tainers, Rootrainers, miniplugs	No	No
Direct Sensor	700	1,300	1,800	2,400	Yes	All but miniplugs	Yes	Yes

(modified from Fisher and others 2006b) *=vacuum extraction, not squeezing

Off the record, this is the reason that growers didn't used to monitor EC very frequently.

Since SME is the lab standard and is the only way to measure absolute EC, researchers have constructed a table to illustrate how the other techniques compare (Table 1). Note that all the techniques are not suitable for bareroot soils. Container size and controlled release fertilizers also have an effect on which of the EC monitoring techniques will work. Miniplugs are so small that they are hard to handle or the stabilized media creates problems; on the other hand, the plug squeeze technique is ideal for miniplugs with stabilized media. It also works well for Jiffy cells, Ray Leach and Spencer-Lemaire containers. Obviously, very large (> 1 gallon) containers have size and weight limitations.

The use of controlled-release fertilizers (CRF) has complicated the measurement of EC. Because the prills are very fragile, even collecting a sample or squeezing it can damage them. Broken prills will release all their fertilizer salts at once and artificially elevate the EC reading. Thus, some of the EC monitoring procedures should not be used when incorporating CRF (Table1).

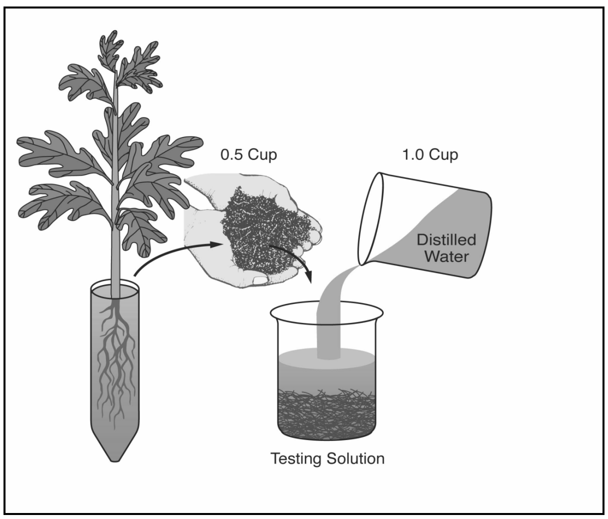

Figure 3 - The 1:2 dilution procedure produces plenty of solution to measure but is destructive and must be calibrated to the SME technique.

1:2 Dilution. This is the most popular of the several dilution techniques and uses 1 part of soil or growing media to 2 parts distilled or deionized water **(**Figure 3). For example, take a half cup of soil or media, place it into a beaker, and add 1 cup of water. Remember that you can't use tap water because it will contain some dissolved salts and will confound your readings. Compress or squeeze the slurry and take your EC reading. This is a popular technique because it gives you plenty of solution to measure but, because it contains much more water than at saturation, your readings will also be "diluted" compared to the standard SME technique (Table1). Also, it's difficult to always use the same amount of pressure to squeeze out the sample solution. However, if you are consistent in the volume and compression of your samples and always sample at about the same degree of soil or media moisture content, the 1:2 dilution will give you good relative EC readings for tracking changes.

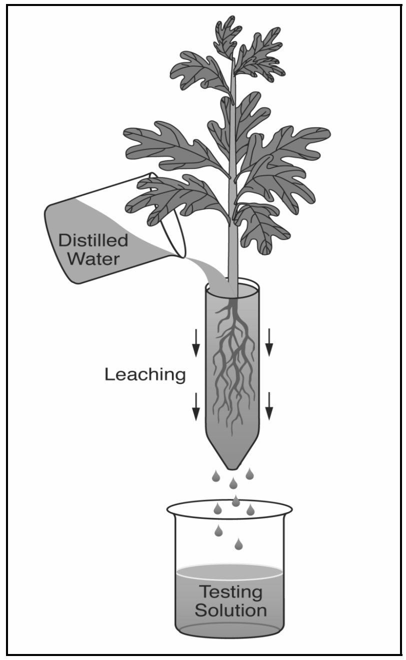

Figure 4 - The pour-through technique works for all containers except miniplugs and larges sizes, and is ideal when using controlled-release fertilizers

Pour-Through. This is a relatively new technique for measuring EC in containers, and works for all container types except for miniplugs where their short height stops the media solution from freely draining. It would also be impractical for very large containers which are difficult to move (Table 1). The pour-through process consists of 2 steps (Figure 4). First, medium in a container is progressively irrigated until saturated, and then left to stand for about 2 hours. Or, just do the procedure 2 hours after irrigation. Next, pour a volume of distilled water onto the media surface to produce about 100 ml of leachate. Of course, this depends on container volume and type of growing media. Make sure and apply the water slowly enough that it doesn't run off and down the insides of the container. The idea is to have the applied water force out the solution surrounding the roots. The pour-through technique is ideal for growing media with controlled-release fertilizers because the prills are not squeezed or otherwise damaged (Table 1). Therefore, this method is ideal for outdoor growing compounds where controlled release fertilizers are the standard.

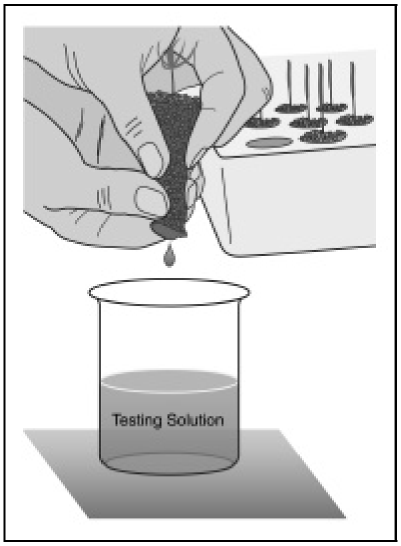

Figure 5 - Although developed for miniplugs, the plug squeeze technique can be used for any containers where the root plug can easily accessed.

Figure 6 - The newest EC meters have probes small enough that you can take measurements directly from soil or growing media.

Plug Squeeze. This procedure, which is also know as the press extraction method, was developed for monitoring miniplugs, especially with stabilized media (Figure 5). It can also be used with Jiffy™ pellets, flexible containers such as RL Cone-tainers™ which can be squeezed, and with Spencer-Lemaire Rootrainers™ where the plug can be easily removed (Table 1). The plug squeeze technique would also work with any container type after the root plug has developed to a point where it can be easily extracted. The plug squeeze technique begins with saturating the plugs and waiting about 1 hour for excess water to drain away. Then, just remove the plugs and squeeze the media solution into a beaker. Depending on plug size, it will take several repetitions before enough solution is obtained to take a reading. The obvious question is whether the amount of squeeze pressure will affect the results, but research has proven that this is not a concern for miniplugs. For larger plugs, however, it would be best to keep the amount of squeeze pressure fairly constant.

Direct Sensor. This last EC monitoring technique has only been possible within the last decade or so because of new instruments such as the Field Scout® Soil & Water EC Meter. These new EC meters have probes small enough that they can be inserted directly into growing media (Figure 6). The obvious advantage of the direct sensor procedure is that readings can be taken quickly and non-destructively. Just be sure that the probe has good contact into the growing medium, and always test at the same media moisture content. The recommendation is to monitor about 1 hour after irrigation or fertigation. Operational testing with this procedure has shown that it works best on miniplugs and other small containers. Readings in larger containers can shown serious variation and so the reading should always be at a standard depth and at the same moisture content. As with any of the other techniques, it would be best to calibrate your direct sensor meter to standard SME measurements (Table 1). Just a word of caution—if you insert the probe into a medium containing CRF and the tip of the probe punctures a prill or is in very close proximity to a prill, the EC reading might be extremely high, requiring a second insertion of the probe into a different area.

Evaluating EC test results

Okay, now that you've got a bunch of EC values from your soil or growing medium, what do they mean? The first thing to remember is that your EC reading is a combination of the base salinity of your irrigation water and dissolved fertilizer salts (Figure 1A):

Soil or Media EC = Water Salinity + Fertilizer

The second consideration is that plants vary considerably in their salinity tolerance and nutritional requirements. Some native plants, like quaking aspen, seem to grow without almost any fertilizer at all whereas others, like western white pine, have to be forced with high fertility levels.

Absolute values. By far, the most research has been done with the SME technique so that should always be your standard. For ornamental plants, researchers have developed some relative ranges when using one of the other field techniques (Table 2). Of course, the best recommendation is to monitor your crops regularly and record the information along with growth measurements and observations on plant health.

Trends. One of the real benefits from monitoring EC during the crop cycle is to develop your own standards and to plot your readings to show trends. Monitoring trends is particularly important when using CRF fertilization where nutrient release is completely dependent on temperature and moisture.

Conclusions and Recommendations

Monitoring electrical conductivity is a good way for growers to keep track of fertilization, and several techniques are available. The most appropriate technique depends on whether you grow in bareroot beds or in containers, the size and type of container, and whether you fertigate or use controlled-release fertilizers. For absolute EC values, the saturated media extract technique is the accepted standard and the other methods can be calibrated to it. Monitoring EC trends also provides very good information and, because the values are relative, any of the techniques can be used.

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Table 2—Interpretation of EC Readings from Soil or Growing Media Using Different Techniques

Fertility Level	SME	1:2 Dilution	Pour-Through	Plug Squeeze
None	0.00 to 0.75	0.00 to 0.25	0.00 to 1.00	0.00 to 1.00
Low	0.75 to 2.00	0.30 to 0.75	1.00 to 2.50	1.00 to 2.50
Ideal	1.50 to 3.00	0.30 to 1.50	1.00 to 6.00	1.00 to 5.00
High	2.50 to 4.00	0.75 to 1.50	4.00 to 6.00	2.50 to 5.00
Danger	>4.00	>2.50	>8.00	>8.00

(modified from Fisher and Argo 2005)