Greenhouse and indoor production of horticultural crops

Substrate versus Fertilizer-based Electrical Conductivity Measurements

Authors:
Ranjeeta Adhikari,
Graduate Research Assistant

Krishna Nemali,
Assistant Professor
Department of Horticulture and Landscape Architecture,
Purdue University
765-494-8179

Electrical conductivity (EC) is an indirect measure of the concentration of ions dissolved in a solution. High tunnels, greenhouses, ornamental nurseries, indoor agriculture and other protected agriculture systems commonly use EC measurements for managing fertilizer application to plants. Readers can access general details about EC from a different article using this link.

One can monitor the concentration of nutrients supplied to plants using the fertilizer EC measurement and assess the concentration of nutrients accumulated in the root zone from substrate EC measurement. Determining substrate EC measurements can be labor-intensive; for example, leachate should be extracted from different locations, whereas one can directly measure fertilizer EC from nutrient solution supplied to plants. Because of this, some growers avoid substrate EC measurements and prefer fertilizer EC measurements. They assume that supplying a fertilizer solution with optimal EC will result in appropriate quantities of nutrients in the root zone. Can fertilizer EC measurements substitute for substrate EC measurements? If not, is there an easy method of measuring substrate EC?

We conducted an experiment, using four petunia varieties in a greenhouse, to understand whether fertilizer EC measurements can substitute for substrate EC measurements. We prepared five concentrations of fertilizer solution with different EC levels – 0.75, 1.5, 2.5, 3.5 and 4.5 dS/m – using Peter's 20-10-20 water-soluble fertilizer. We grew all four petunia varieties in each fertilizer solution and replicated the trial four times to increase the accuracy of our results. We measured fertilizer EC using a 5TE EC sensor manufactured by Meter Group Company (Figure 1). For substrate EC, we used pour-through method (see this link for details on the method). First, we collected leachate from the substrate, and then we measured EC of the leachate (using the same EC sensor as in Figure 1) to estimate substrate EC. Six weeks after transplanting, we measured the weight of petunia plants in each fertilizer treatment.

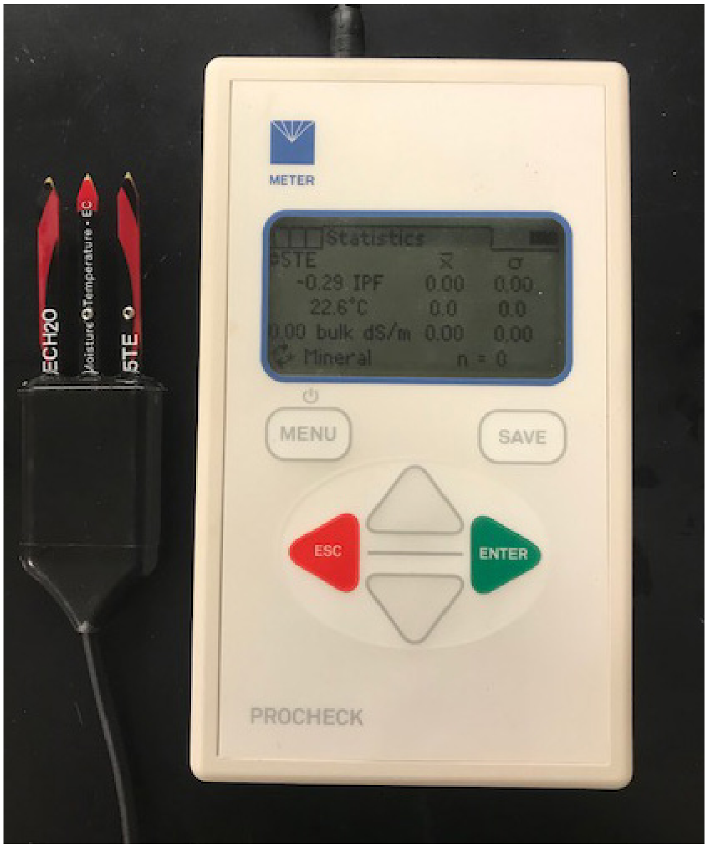

Figure 1. 5TE sensor from Meter Group used to measure electrical conductivity (EC) of the solution

The average weight of petunia plants increased as fertilizer EC increased. The weight increase happened up to 2.5 dS/m. When fertilizer EC was higher than 2.5 dS/m, the change in weight was small (Figure 2). Average plant weight changed less than 10 percent between 2.5 and 4.5 dS/m. This means that plant weight was less sensitive to fertilizer EC between 2.5 and 4.5 dS/m. The response is surprising; one would expect a decrease in weight of petunia at high fertilizer EC levels (see publication by Nemali and van Iersel, 2004). By further examining data in Figure 2, one sees large variation in the weight of individual plants within each fertilizer treatment. The variation was not due to growing different varieties within each fertilizer treatment. In fact, there was large variation in weight among the plants belonging to the same variety. One possibility is that some other factor affected plant growth in addition to fertilizer EC, and there was likely large variation in the other factor within a fertilizer EC level. The effect of the other factor on plant weight appears stronger than that of the fertilizer EC.

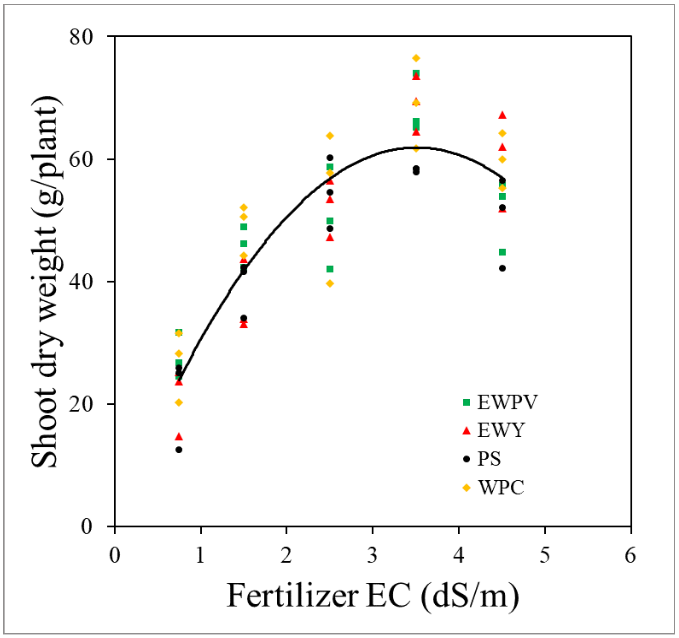

Figure 2. Relationship between plant weight and fertilizer electrical conductivity (EC). Data from four petunia varieties is shown

We tested whether the additional factor affecting plant weight is substrate EC. For this, we first related substrate EC and fertilizer EC measurements (Figure 3). Substrate EC generally increased when fertilizer EC was increased. However, we found a large variation in substrate EC within each fertilizer EC level, similar

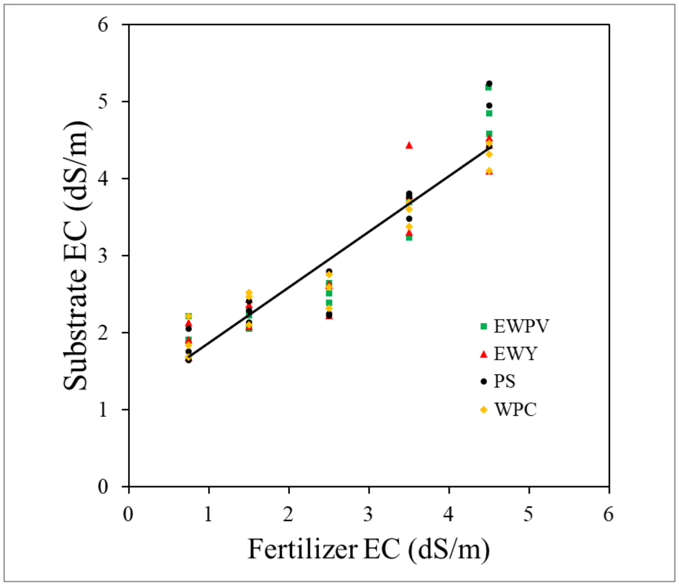

Figure 3. Relationship between substrate electrical conductivity (EC) and fertilizer EC in petunia varieties

to the variation observed for plant weight. Substrate EC was different in pots supplied with the same fertilizer solution. This means that the concentration of nutrients in the root zone varied despite similar fertilizer EC supplied to the substrate. Several factors affect substrate EC measurements in addition to fertilizer EC. These include irrigation uniformity, pH of the solution, compactness of the substrate, and plant growth rate. If irrigation volume is not uniform among the pots, then different pots can receive different quantities of nutrients, thereby leading to differences in substrate EC. The pH differences can increase or decrease availability of fertilizer ions in the root zone, leading to differences in plant nutrient uptake. Compactness of the substrate can affect water and nutrient retention in the pot. Loosely packed substrates can have large macropores, which can increase leaching and loss of nutrients from the substrate. Finally, fast-growing plants tend to decrease substrate EC, while slow-growing plants increase substrate EC. Note that the above factors can affect substrate EC in pots despite supplying the same fertilizer solution to the pots. Therefore, we suspected that the differences in substrate EC, likely due to presence of varied amount of nutrients in the root zone, was the main reason for observing variation in the weight of plants belonging to a variety within the same fertilizer EC level.

Further, the relationship between plant weight and substrate EC was much tighter than that observed between the plant weight and fertilizer EC (Figure 4). The spread in data on both sides of the average response line in Figure 4 was much smaller than that seen in Figure 2. Moreover, we found that plant weight of petunia increased up to a substrate EC level of 3.75 dS/m. Plant weight decreased when substrate EC increased above this level. This further suggests that plant weight is more sensitive to substrate than fertilizer EC. The likely reason for decrease in plant weight at high levels of substrate EC is osmotic stress. High concentration of nutrients in the root zone can cause osmotic stress on roots, similar to adding salt solution to the roots. Because the substrate EC varied within a fertilizer EC level, some but not all plants likely experienced osmotic stress. Thus, there was a large variation in the plant weight within a fertilizer EC level. **Based on our experimental results, one should not substitute fertilizer EC for substrate EC measurements.**

Before developing an easier method, it is important to understand why substrate EC measurement is time-consuming. There are three common methods of measuring substrate EC: pour-through, saturated media extraction (SME), and 1:2 dilution methods. Pour-through method involves adding a small volume

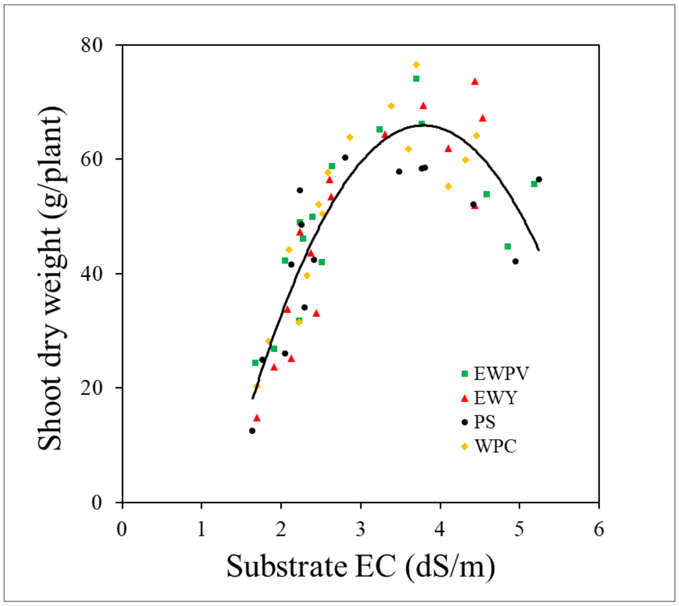

Figure 4. Relationship between plant weight and substrate electrical conductivity (EC) in petunia varieties

of water uniformly at the top of a substrate several minutes after thorough irrigation. The added water pushes the existing water in the substrate pores out of the pot and into a saucer placed below the pot. The EC of water collected in the saucer is a measure of substrate EC. The SME method involves slowly and uniformly adding deionized water to the substrate placed in a watertight container until a film of water just starts to appear on the surface. The 1:2 dilution method involves mixing one part of dry substrate with two parts of deionized water. In both the SME and 1:2 methods, the added water comes into equilibrium with pore-water in a couple of hours after addition/ mixing. Then the solution is extracted by filtering substrate particles, and substrate EC is determined by measuring the EC of the extract. The pore-water extraction methods involve several steps, making substrate EC measurement time-consuming and less popular.

More growers likely would consider adopting substrate EC measurements if provided with a simpler technique for measuring substrate EC. There is another estimate, called "bulk EC," for substrate EC determination. That method uses substrate EC probes similar to the one shown in Figure 1. There are a few things to keep in mind about bulk EC measurement. In addition to the concentration of fertilizer ions in the root zone, both substrate particles and substrate air influence bulk EC measurement. That is why the bulk EC measurement is lower than other methods described above. Moisture content of the substrate can affect the accuracy of bulk EC measurement. For example, when more water evaporates from the substrate, the moisture content decreases and concentration of fertilizer ions increases. This can artificially increase substrate EC. Thus, it is important to make bulk EC measurements at similar moisture levels in the substrate. The bulk EC measurement can vary from location to location within a pot because the probe measures a small volume of the substrate each time. For example, rooting density can affect moisture content of the substrate. Because rooting density can vary inside a substrate, bulk EC assessments from small volume of substrate can be highly variable. Regardless, the main advantage is that the bulk substrate EC method is rapid and less intensive in nature than the pore-water EC method. One can reduce the variability in bulk EC by using high-quality probes and taking 3-4 measurements from different locations within a pot and averaging the values. Further, one can develop a relationship between bulk EC and pore-water EC and equate bulk EC measurements to commonly used substrate EC methods.

As an example, we developed a relationship between pore-water EC and bulk EC by adding solutions with different fertilizer EC levels to the substrates in different pots. First, we measured bulk substrate EC measurements by inserting the in situ probe (Figure 1) into the substrate at three locations and averaging values for each pot. Then, using pour-through method, we collected pore-water from the same substrates used for bulk substrate EC measurements. We plotted the data from both measurements to study the relationship between pore-water EC and bulk EC (Figure 5). There was a tight relation between the pore-water EC and bulk EC measurements. As expected, the value of pore-water EC was 1.8 times higher than that of bulk EC measurement. Scoggins and van Iersel (2006) observed similar results in their research on pore-water and bulk water EC measurements. The values of bulk substrate EC and pore-water EC are interconvertible using the relationship in Figure 5. However, the relationship between pore water EC and bulk EC can vary from substrate to substrate. **Therefore, it is possible to simplify substrate EC measurements using direct probes and to convert probe measurements to other commonly used substrate EC measurements.** However, growers should develop a separate conversion factor for each substrate. This is not an issue as growers commonly use a specific type of substrate. They can develop a conversion factor one time and use it repeatedly.

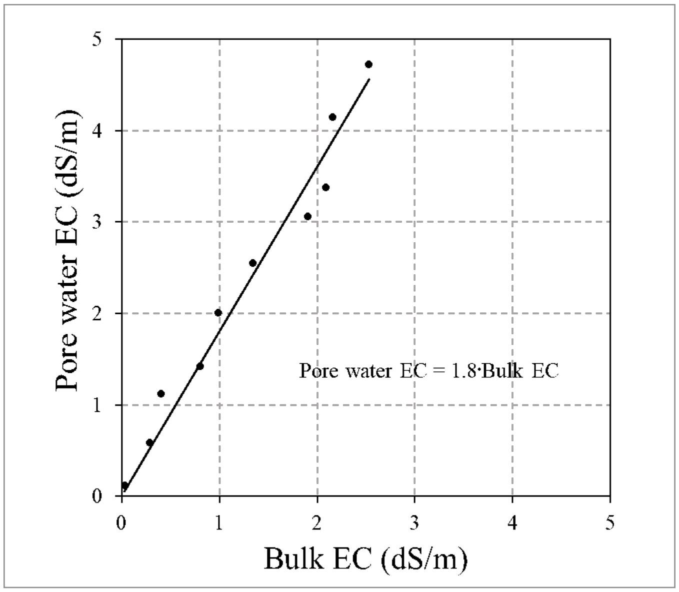

Figure 5. Relationship between pore-water and bulk substrate EC

In conclusion, the substrate EC measurements should not be substituted by fertilizer EC measurements. By using in situ substrate EC probes, growers can quickly and easily measure bulk substrate EC as needed. Using the substrate-specific relationship between the pore-water and bulk substrate EC, growers can convert in situ probe measurements to pore-water EC for comparison.

Questions?

For questions related to substrate EC and measurement, growers can contact Dr. Krishna Nemali by phone (765- 494 8179) or email (knemali@purdue.edu).

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