How Precise Is Your Soil Test?

Internal Report for Young Plant Research Center Partners.

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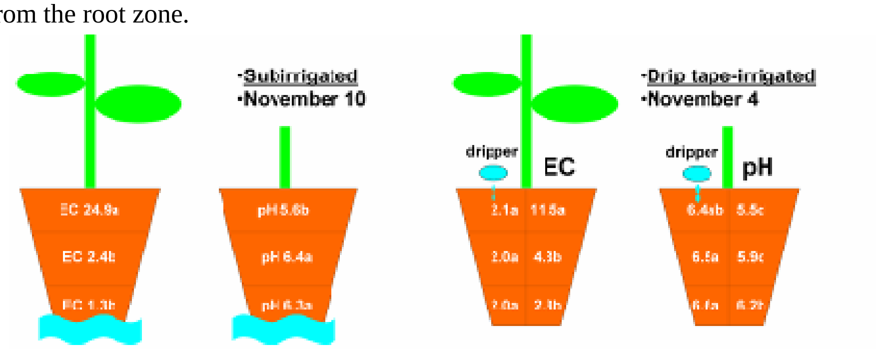
Executive Summary

- Fertilizer decisions are usually based on pH and electrical conductivity (EC) from one soil sample (e.g. for the saturated medium extract (SME) or the 1 soil:2 water method), drawn from several combined pots. Alternatively, with the pour-through method or using direct sensor probes, the pH and EC results from several individual pots are averaged. It is therefore useful to quantify variability both between pots and within a pot.
- With any soil test, there is some error in the reading you obtain, and the precision of a soil test can be statistically described in terms of 95% confidence intervals. If the precision of a soil test is ±0.17 pH units, for example, then if a single soil test reading is 5.0 then the true average pH for the entire crop is likely to be somewhere between 4.83 to 5.17 (a range of 0.34 pH units).
- We collected soil samples from 480 10-inch pots of poinsettia growing in two greenhouses in New England, and measured pH and EC using the SME method, on samples from single pots or randomly combined from five pots. We also divided pots into six sectors and collected media from each sector.
- We found that taking an SME based on one single-pot sample would give a precision for pH of ±0.26 pH units and precision of EC was ±0.98 milliSiemens/centimeter (mS/cm). We found that using one sample drawn from five pots increased the precision of the results to ±0.17 pH units and ±0.62 mS/cm for electrical conductivity.
- This level of precision (or lack thereof) should be considered by crop managers to avoid overreacting to trends in soil tests, especially for EC. Precision will be lower still if using a sensor with low resolution, or when sampling in a highly variable crop. Inaccuracy (incorrect readings) is a further problem if the sensor is poorly calibrated.
- Considerable salt stratification (and resulting variation in EC) occurred in subirrigated and drip-irrigated crops, affected by evaporation from the soil surface and leaching from surface application of the nutrient solution (see figure below). EC was about 20 times higher near the soil surface for subirrigated crops compared with the bottom third of the pot. pH decreased as EC increased. There was also variation from the drip to non-drip sides of drip-irrigated crops. These results emphasize the importance of taking the soil sample in a consistent manner from the root zone.



Introduction

Standard recommendations for sampling container growing media for laboratory or onsite testing using a saturated medium extract (SME) or 1 soil:2 water by volume (1:2) test are to collect between one cup and 400 mL of growing media from 5-10 pots ((Warncke, 1995; Whipker et al., 2002), and to blend this growing medium together as a single sample.

It is also recommended to take the sample from the middle 1/3 of the container, or from the entire soil profile excluding the top ½ inch (1.2 cm) in order to avoid erroneous readings from the salt layer in the top of the container (Whipker et al., 2002).

In addition to the SME and 1:2 methods, other protocols are also used that vary in the sample size. Increasing numbers of growers measure soil pH and electrical conductivity (EC) using either a pour-through method to test leachate (Cavins et al., 2004; Nelson, 2003), or using commercially available sensors which directly measure pH or EC in the growing medium (Spectrum Technologies Inc., Plainfield, Ill.). In these latter two methods, the sample size is one individual container, and five single-pot samples are recommended for pour-through analysis by Whipker et al. (2002). A further "press extraction" or "plug squeeze" testing method (Scoggins et al., 2002) is used for small cells, where the soil solution is extracted from the sample by physical pressure on the soil surface, from one row on at least five trays (Whipker et al., 2002).

Nutrient management decisions (fertilizer concentration and composition) are made based on regular monitoring, usually relying on a single sample. With any soil test, there is some error in the reading obtained. This error results from slight differences in the testing procedure over time, limits to the resolution and accuracy of the pH or EC meter, variation between plants in their rate of nutrient uptake, and differences in the media and fertilizer supply from pot to pot. It is therefore useful to know the precision of media-pH and media-EC samples. We focused on the SME method in this report, and other soil testing methods are discussed in other reports.

Objectives

1) To quantify how much variability there is in the pH and EC of growing media within a commercial greenhouse crop, and how that affects precision of soil samples.

2) To quantify how pH and EC differ between the top, middle, and bottom layers of soilless media inside pots under different irrigation systems.

Research Methods

For objective 1, we measured pH and EC on poinsettias in two commercial greenhouse sites in the northeastern United States. Management in the two locations is summarized in Table 1. Each site had a different irrigation method (subirrigation or drip-tape irrigation). Because of differences in media and other management practices at each location (Table 1), our analysis cannot statistically identify why there were soil test differences between sites – it may have been caused by irrigation methods or some other management factor.

Table 1. Management of each crop used in sampling for objectives 1 and 2.

Site:	Massachusetts	New Hampshire
Objectives	1 and 2	1 and 2
Irrigation method	Drip tape	Subirrigation on concrete floor
Pot diameter	10-inch	10-inch
Fertilizer concentration	200ppm	250ppm
Fertilizer type	17-4-17 or 13-2-13	Combinations of 15-3-16, 20-10-20, 15-0-15, 17-4-17, 15.5-0-0, 10-0-0 plus micros
Growing medium	Custom: 30% composted pine bark, 55% peat, 15% perlite	Fafard 3B with high lime
Planting date	7/13/04	7/5/04
Measurement date	11/4/04	11/10/04

For objective 1, we sampled pots arranged in bays in the commercial greenhouses. In the drip-irrigated "Massachusetts" site, 20 pots were measured in each of 9 bays, which included 5 different cultivars (Prestige Red, Orion Red, Whitestar, Maren pink, and Cortez White and Red combination pots (photo)). For the subirrigated "New Hampshire" site, we sampled 30 pots in each of 10 bays, which included 5 cultivars (Prestige, White Star, Monet Twilight, Freedom White and Red combination pots). From each pot, we collected 1/4 cup of growing medium from each of four locations around the bottom one-third of the soil profile. One half of this combined cup of sample was measured separately to provide a pH and EC measurement for the individual pot. We also combined the remaining ½ cup from random groups of 5 pots together to obtain a blended five-pot sample (combining subsamples from 5-10 pots is the usual recommended way to measure pH and EC). The saturated medium extract (SME) method was used with deionized water as the extractant to measure pH and EC, using calibrated desktop pH and EC meters. A Corning Scholar 425 pH meter with a "High-Performance" pH probe was used for objective 1, and an Orion model 520A pH meter (Orion Technologies, Beverly, Mass.) with a gel-filled SensoreX S200C pH probe (SensoreX, Garden Grove, Cal.) was used for other experiments reported here. An Orion model 130 electroconductivity meter was used for all EC measurements.

For objective 2, we sampled 10 pots of one cultivar (Prestige) from within one bay at each of the two sites. The pots were sampled in 6 locations within the soil profile – either the North and South sides of the pot (subirrigated) or the dripper and non-dripper sides of the pot (drip-tape irrigated pots), and at the top, middle, and bottom third of each pot. Samples (½ cup) of medium were removed from each of the 6 locations within the soil profile and were measured separately. pH and EC of each sample was tested using the SME method. pH and EC were analyzed separately for each site using ANOVA, with pot side, vertical layer, and interaction terms.

A second trial is being run for objective 2 at UNH during summer 2005. In that trial, we are growing poinsettias with subirrigation, drip irrigation, and hand watering (20 8-inch pots per treatment), and collecting data using the SME and pour-through methods.

Results

<u>Objective 1. Variation between pH and EC samples</u>

pH and EC samples were considered to be normally distributed around the means, based on statistical tests of normality for within-crop distributions of pH and EC using the Shapiro-Wilk test at the p=0.05 level. Testing single pot samples, 14 out of 17 EC and 13 out of 17 pH distributions were normally distributed. For the 5-pot samples, 15 of 17 EC and 16 of 17 distributions were normally distributed. Therefore, data were not transformed in the analysis.

There were statistically significant differences in pH and EC between bays of plants (Appendix 1). The mean media-pH ranged from 5.75 to 6.33, and the media-EC ranged from 1.42 to 3.53 mS/cm (Appendix 2). These data were mainly within the acceptable pH range for poinsettia (5.4 to 6.2, Nelson (2003)) and were within the acceptable (0.75 to 2.0 mS/cm) to optimum (2.0 to 3.5 mS/cm) range of EC for the SME test (Warncke, 1995).

A useful result from the ANOVA tables (Appendix 1) was the mean-square error, which represents the remaining, unexplained error and indicates the variability within a particular bay that is not explained by between-bay differences. For single pot samples, the mean-square error for media-pH was 0.017, and the mean-square error for media-EC was 0.249. For five-pot samples, the mean-square error for media-pH was 0.0072, and the mean-square error for media-EC was 0.1005. These results show greater variability in media-EC than media-pH in both absolute terms and also relative to the mean pH and EC levels.

This statistical analysis can therefore be used to calculate the precision of soil tests based on a certain number of samples (Table 2). The table shows different numbers of soil test samples in the left column. The precision was estimated for samples that are drawn from individual pots ("Single-pot samples") or five pots blended together. Table 2 is therefore a measure of the precision or consistency of pH or EC measurements compared with the actual ("population") mean measurement.

We statistically describe the precision of a soil test result in terms of 95% confidence intervals. If the precision of a soil test is ±0.17 pH units, for example, then if a single soil test reading is 5.0 then the true average pH for the entire crop is likely to be somewhere between 4.83 to 5.17 (a range of 0.34 pH units). For example, if pH and EC are measured in five single-pot samples, the precision of the pH measurement would be ±0.12 pH units and ±0.44 EC units.

With one five-pot sample, precision would be ±0.17 pH units and ±0.62 EC units.

With one single-pot sample, precision would be only ±0.26 pH units and ±0.98 EC units.

Table 2. Precision (95% confidence intervals) for media-pH and media-EC measurements using the Saturated Medium Extract (SME) method with deionized water as the extractant.

	Single-pot samples		Five-pot samples	
Variance	0.017	0.249	0.007	0.100
Standard deviation	0.131	0.499	0.085	0.317
Number of samples	pH	EC (mS/cm)	pH	EC (mS/cm)
1	0.26	0.98	0.17	0.62
2	0.18	0.69	0.12	0.44
3	0.15	0.56	0.10	0.36
4	0.13	0.49	0.08	0.31
5	0.12	0.44	0.07	0.28
6	0.11	0.40	0.07	0.25
7	0.10	0.37	0.06	0.23
8	0.09	0.35	0.06	0.22
9	0.09	0.33	0.06	0.21
10	0.08	0.31	0.05	0.20
12	0.08	0.29	0.05	0.19
15	0.07	0.28	0.05	0.18
20	0.07	0.27	0.05	0.17
25	0.07	0.26	0.04	0.17
50	0.07	0.25	0.04	0.16
100	0.06	0.22	0.04	0.14

In comparison to Table 2, repeated measurements of a single SME sample with the Corning pH meter, Orion pH meter, and Orion EC meter resulted in a standard deviation of ±0.046 pH units, 0.012 pH units, and 0.009 dS/m, respectively. Therefore, most of the variation shown for small sample sizes in Table 2 is probably because of variation between soil samples, rather than lack of resolution or precision of the meters themselves.

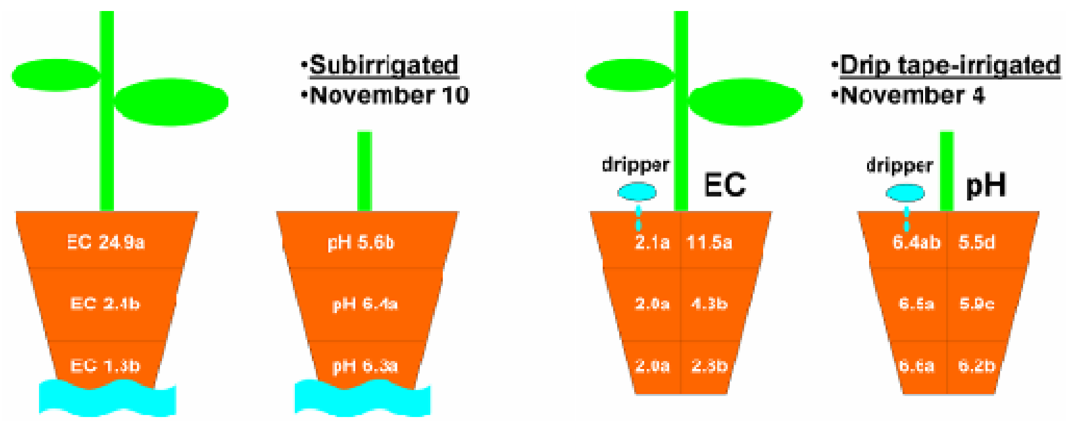
Whipker et al. (2002) surveyed a range of portable pH and EC meters used by U.S. growers. The resolution for pH meters ranged from ±0.01 to 0.1, and for EC meters was ±0.01 to 0.1 mS/cm. Accuracy (whether readings tend to be biased too high or low) ranged from ±0.01 to 0.2 pH units, and 1% to 2% for EC meters.

<u>Objective 2 Variation between the top, middle, and bottom layers of the growing medium</u>
For subirrigated pots, as expected, there were no differences between North and South sides of the pot. However, there were major differences between the pH and EC on the top-third layer compared with the bottom two thirds (Figure 1). EC was more than ten times higher in the top of the container compared with the bottom two thirds, where most of the roots were growing.

For drip-irrigated pots, there were major differences between the two sides of the container, and the vertical stratification down the media profile also varied between the two sides. On the dripper side of the pot, the leaching of fertilizer solution meant there was no vertical stratification in EC or pH. On the non-dripper side, EC increased up the container because an upper salt layer was able to develop. pH declined as EC increased, with the lowest pH on the top, non-dripper side.

These results emphasize the importance of sampling the container in the root zone, i.e. the area that roots are actively growing, and avoiding the upper salt layer of the container. It is also interesting to observe the complex salt distribution for drip-irrigated containers, and given the uneven salt distribution for the drip-irrigated containers in this study, it is unlikely that water and fertilizer distribution was optimum.

Figure 1. EC and pH distribution in subirrigated and drip-irrigated containers.



Note: mean values that share the same letters are not significantly different using Tukey's HSD mean comparison test at the p=0.05 level.

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