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In situ probes for direct measurement of substrate soluble salts: effects of substrate moisture content and fertilizer concentration

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The reporting guidelines for measuring and reporting environmental parameters in controlled environment research call for measurements of electrical conductivity (EC) in liquid culture, but not in soilless substrates. However, EC is a useful indicator of the nutrient content of soilless substrates as well, and may be a relevant parameter in many experiments. Several probes have recently been developed that can be inserted directly into the growing medium to get electrical conductivity (EC) measurements. Some of these probes are able to measure the EC of the pore water in the substrate [W.E.T sensor, SigmaProbe (both from delta T)], while other meters measure the EC of the bulk substrate, together with the solution in it [FieldScout (Spectrum Technologies), HI 76305 (Hanna Instruments)]. We tested whether these probes are indeed sensitive to substrate EC, and how these measurements may be affected by temperature and volumetric water content of the substrate. In addition, we compared these probes to standard laboratory methods to measure substrate EC [1:2 v/v dilution, saturated media extract (SME), and the pour-through method].

The FieldScout and SigmaProbe both had very low temperature sensitivity, and the temperature correction for the SigmaProbe can be changed by the user (1.7% generally works well). The W.E.T sensor was temperature sensitive at high EC (5 dS m^{-1}), but this is outside of the specified operating range for this sensor. Although the temperature compensation of the W.E.T probe can also be user-adjusted, we were not able to find a temperature correction that worked at all EC values. The HI 76305 probe was extremely temperature sensitive. In addition, this probes report 'salinity' in units of g/L instead of EC. The conversion from EC to salinity does not appear to be according to standard practices (1 dS m^{-1} = 640 - 700 ppm), which makes it difficult to compare readings to those collected with other methods.

Table 1. Regression coefficients of EC measurements from *in situ* probes versus standard laboratory methods. To convert values from a standard laboratory method (y) to an *in situ* probe measurements (x) use: x = intercept + slope × y.

In situ probe	Laboratory method	Intercept	slope	r^2
W.E.T probe	PourThrough	0.74	0.573	0.93
	1:2 dilution	0.71	2.07	0.92
	SME	0.66	0.795	0.94
SigmaProbe	PourThrough	0.62	0.599	0.96
	1:2 dilution	0.57	2.19	0.97
	SME	0.61	0.805	0.91
FieldScout	PourThrough	0.34	0.611	0.95
	1:2 dilution	0.29	2.23	0.95
	SME	0.25	0.849	0.96
HI 76305	PourThrough	0.34	0.155	0.93
	1:2 dilution	0.33	0.566	0.93
	SME	0.32	0.213	0.91

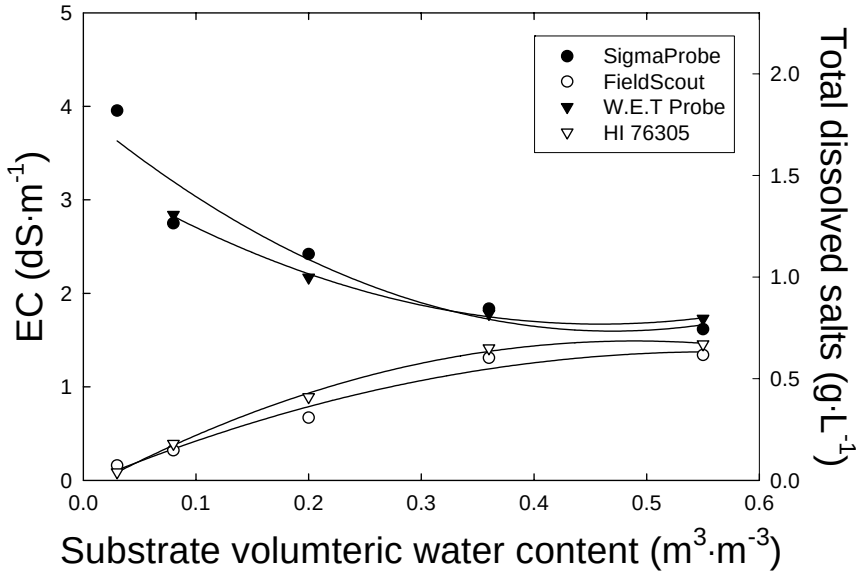

Figure 1. The effect of substrate moisture content on the EC reading of different probes. VWC was altered by adding de-ionized water, so the total amount of soluble salts was the same in all treatments. HI 76305 measurements are in units of g·L^{-1}.

The substrate volumetric water content (VWC) affected the *in situ* probes differently, based on whether they measure solution or bulk substrate EC (Figure 1). The SigmaProbe and W.E.T Probe measure the EC of the pore water specifically and show a decrease in EC with increasing water content, as the fertilizer ions in the pore water become more diluted as VWC increases. Results with the Hanna and FieldScout probes increased with increasing water content as the added water helps to provide better contact between the electrodes of these meters. There was little sensitivity to VWC when VWC exceeded 35%.

The EC measured with the various *in situ* probes differed slightly among the probes but was highly and positively correlated with all three of the solution extraction methods over the range of fertilizer concentrations (r^2 > 0.91; Table 1, Figure 2). Substrate VWC during these measurements was ~ 50%. This makes it possible to convert substrate EC guidelines that have been established for any of the laboratory methods for use with the *in situ* probes, though our results indicate the substrate VWC must be above 35% for the interpretation to be valid. The *in situ* probes are a viable alternative for measurements of substrate EC that would eliminate the step of substrate solution extraction.

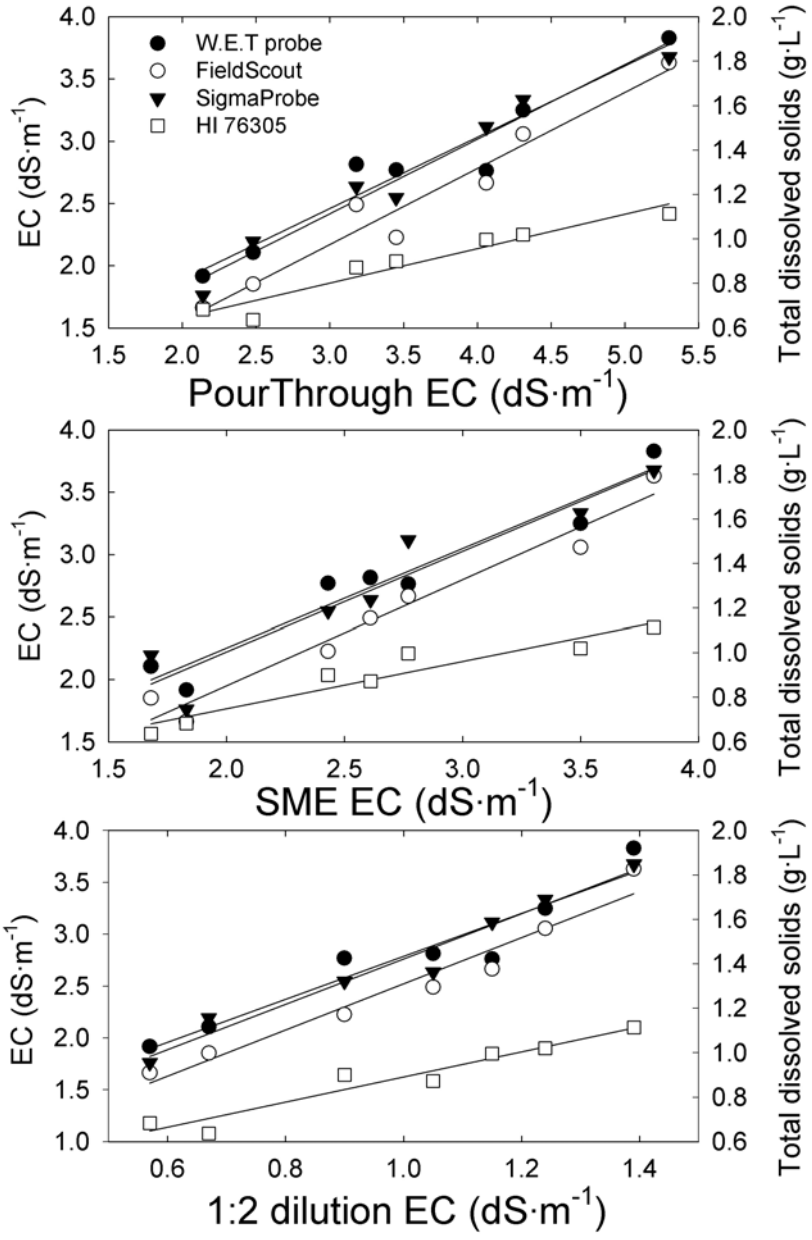

Figure 2. Correlation between EC readings of various probes and different laboratory methods. See table 1 for regression results. HI 76305 measurements are in units of g·L^{-1}.