Calibration of Ech$_2$0 Probe Sensors to Accurately Monitor Water Status of Traditional and Alternative Substrates for Container Production

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Significance to the Industry: Growers in many countries are searching for alternative substrates for use in container production that will maintain optimal plant growth and production. In Costa Rica, some growers are using a native gravel substrate to grow ornamental crops rather than using costly imported substrates such as peat. Although this native quarry gravel is cheap, growers recognize that it needs to have adequate physical and chemical properties to provide sufficient water-holding and aeration conditions for specific crops. In addition, irrigation scheduling for crops grown in this gravel substrate is more difficult than for traditional substrates because of its weight and porosity. The typical methods of 'sensing' the water content of a substrate (e.g. picking up the pot, visually examining the rootball, using touch to sense the moisture status of the substrate) are not very applicable to this gravel substrate, since it is heavy, easily falls apart and does not appear to be wet, even soon after an irrigation event. In addition, plant species of interest in this experiment *Kalanchoe Blossfeldiana* [Poelin] is a desert-adapted succulent species, and does not show typical symptoms of plant wilt, even when the plant is severely water-stressed. It typically grows best in a well-aerated substrate for optimal growth, especially when grown under intensive greenhouse conditions for commercial shoot-tip production [3, 4].

The Ech$_2$0 capacitance probes (Decagon Devices, Pullman, WA) were chosen to sense the available water in two substrates, therefore enabling the grower to schedule irrigation events more accurately. Although some nursery and greenhouse operations use gypsum or Watermark™ blocks, and/or tensiometers to sense the water status of soilless substrates, previous research and grower experience has typically shown that these tools do not provide reliable data in soilless substrates with air-filled porosities above 15-20%. We chose to use Ech$_2$0 probes because they are relatively cheap and easy to use for scheduling irrigations [9], if calibrated correctly. Ech$_2$0 probes, like time domain reflectometry (TDR) probes, sense the water status of the substrate by measuring the dielectric permittivity (potential) of the water contained in the soil volume, by using a reference value of 81 for water and 0 (infinity) for air [9, 8, 1]. With correct calibration, TDR sensors have been shown to accurately sense the water content in both soils [9, 8, 1] and a variety of soilless substrates [5, 6, 7], if calibration and placement issues are resolved [1, 5, 7, 8]. In addition to the substrate's physical properties, the interaction of the height of a container is well-known to affect the plant available water in a substrate [2].

Nature of Work: The purpose of this study was to measure the performance of Ech_20 probes in two substrates, namely peat (Pindstrup Peat, Denmark) and a local quarry gravel (Alajuela, Costa Rica), in two container types {a 1.1 gallon (4.25 L) 'pot' container and a 2.15 gallon (8.15 L) 'flat' container}. The calibration experiment was first accomplished for the peat substrate (Experiment 1) and then for the gravel substrate (Experiment 2), each over a 10-day period. Six randomized blocks of nine pots and three flats containing two and six Kalanchoe plants per container, respectively, were laid out in a greenhouse at the Fabio Baudrit Moreno Research Centre near Alajuela, Costa Rica. Twenty-cm long Ech_20 probes were used in the pot container 7.87 in (20-cm) high and 3.94 in (10-cm) long Ech_20 probes were used in the 3.15 in (8-cm) flat container. Probes were inserted into the middle container of both substrates at a 45º angle to sense the entire rooting depth of each container. Other plants and pots constituted guard rows for each block. The plants were irrigated to container capacity for three days prior to the initiation of each experiment (day 0). Containers were not watered thereafter, until pre-dawn and mid-day leaf water potential (ψL) measurements (data not shown) indicated the plants were showing temporary water stress (approximately 8-9 days later). All containers (containing the probes) were weighed at 0800 h every day, and the data recorded. The Ech_20 probe data were measured continuously using a Campbell CRX-10 datalogger and a modified datalogger program (Ech_20 probe manual) over the duration of each study. From these data, the mean plant available water for each container and substrate was calculated. The mean probe mV reading and the container weigh at 0800 h were used to derive the regression equations for each substrate / container combination (Figure 1, 2).

Results and Discussion: *Plant Available Water.* Calibration data were measured from container capacity (day 1) until plants exhibited temporary water stress. This occurred at day 9 in peat (Figure 1) and day 8 in the gravel substrate (Figure 2). Measurement of this total volume represented the total plant available water in each substrate/ container combination (Figure 1, 2). The volumetric ratio of the containers was 1.91 (= 8.15 L / 4.25 L). However the plant available water content of the flat container was nearly three times that of the pot container with the peat substrate (Figure 1) and over 2.33 times that of the pot container with the gravel substrate (Figure 2). This confirms that container height has a disproportionate effect on the water holding capacity of any substrate, and that growers should be aware that tall containers hold less water and therefore require more frequent irrigations. The gravel substrate in this study held considerably less water than the peat substrate, indicating that this substrate would need more frequent irrigations, especially with the high plant densities (six plants per flat container) commonly used by the commercial operation using this production system.

Calibration Data and Probe Function. The precision (probe-to-probe variability) of both Ech_20 probe sensors was good throughout the range of plant available water in both substrates and container shapes (Figure 1, 2). However, one of the 10-cm probes gave spurious data throughout both calibration studies and these data were eliminated from the results. Some probe-to-probe variability was noted in the gravel substrate (Figure 2) which was mainly due to the offset value of the factory calibration; for that reason we decided to show the data for each probe. The slope and goodness of fit of the regression equations were very highly significant ($P<0.001$) in all tested combinations, i.e. each probe precisely measured the plant available water content of the gravel in each container. The calibration values shown in Figures 1 and 2 can be used to substitute for the calibration settings provided by the manufacturer.

This paper describes a practical method to more accurately calibrate Ech_20 probe sensors for two diverse horticultural substrates of differing composition and structure. These data show that this specific substrate calibration is more important when sensors are used in pots of differing heights, confirming the fact that container height affects the water holding capacity of any substrate [2]. Growers and irrigation consultants should perform these calibrations before using these sensors in growing operations, although it is noted that the factory calibration is probably adequate for gross irrigation control. If calibrated for specific substrates and container heights, it appears that Ech_20 probes will give precise measurements of plant-available moisture and that these measurements can be used to schedule irrigations more accurately in greenhouse and nursery production.

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Figure 1. Plant Available Water (PAW) vs. Ech₂0 probe output (mV) for peat substrate in two containers.

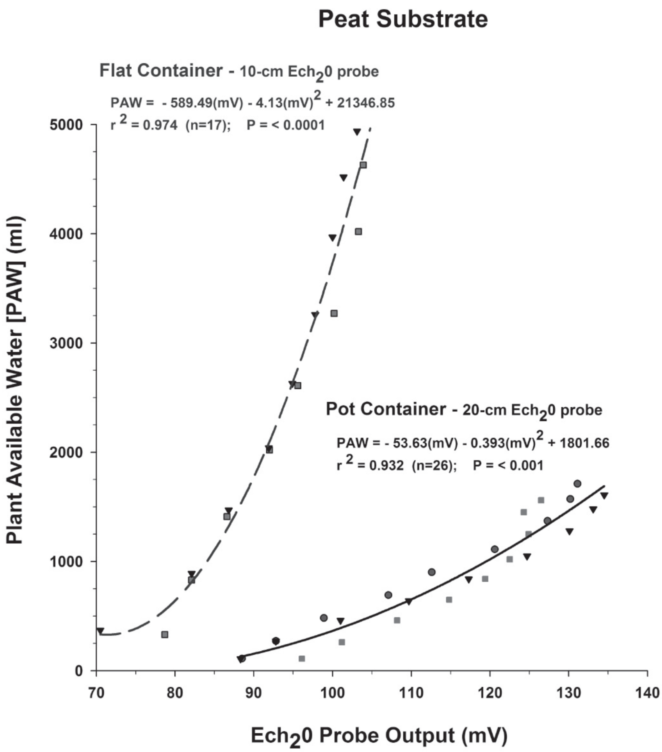

Figure 2. Plant Available Water (PAW) vs. $Ech_2 0$ probe output (mV) for gravel substrate in two containers.