Revisiting the Measurement of Plant Available Water in Soilless Substrates

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Significance to the Industry: In the nursery industry, irrigation management is the key cultural practice that determines the extent of nutrient runoff. We are testing soil moisture capacitance sensors (Ech$_2$0 series; Decagon Devices, Pullman, WA) to monitor and control irrigation scheduling in soilless substrates. By comparing these results of this research with past published studies on water availability in soilless substrates, we intend to ensure that we can precisely integrate these and other environmental sensors into wireless networks for real-time management. Eventually, these sensor networks may revolutionize our approach to water and nutrient management, making more efficient use of resources by reducing water consumption and nutrient runoff.

Nature of Work: Previous studies on water desorption curves [2, 3] showed definitive differences between soil and soilless substrates in the availability of water for roots. Soilless substrates, which in most cases have larger particle sizes, tend to release more water at much lower pressures than in most soils. Plant Available Water (PAW) is defined as the amount of water accessible to the plant, and this is affected by the physical properties of the substrate. Some researchers propose that soil moisture availability varies from 0 to about 1.5 MPa (wilting point). However, in soilless substrates, plant wilt begins at substrate moisture tensions much lower than 1.5 MPa, and growth reductions can occur at tensions as low as 16 kPa [7, 8]. Water status in soilless substrates has been recognized as critical because of the limited amount of water in container production [6, 5]. The objective of this research was to compare the previous literature with our data for readily-available water (RAW; 01-10 kPa substrate moisture tension) and progressively unavailable water (PUW; >10 kPa substrate moisture tension).

An examination of RAW for plant growth was performed on five soilless substrates to gather simultaneous water desorption curves with capacitance sensor readings. We wanted to compare these results to previous methods and results [6, 2, 4]. Substrates included Perlite (horticultural grade A-20, Pennsylvania Perlite Corp., Bethlehem Pa.), two commercial nursery mixes [5 pine bark: 1 sphagnum peat moss namely (*A*), and 100% pine bark namely (*B*)], Sunshine Professional LC1 (4 sphagnum peat moss : 1 perlite) and 100% Sri

Lankan coir (coconut fiber). These substrates were chosen on the basis of their use in the container nursery industry and/or their differing ability to hold and release water. Desorption curves were generated for each substrate with simultaneous readings using 20 cm long Ech$_2$O capacitance probes (Decagon Devices, Pullman, WA), a custom-built desorption table, and positive (compressed air) pressure. Ten simultaneous replicate columns were simultaneously desorbed for each substrate with each run. Columns were 20.7 cm tall x 12.7 cm diameter (packed uniformly to the top) to represent the height of a substrate column in a container. Each sealed column had a capacitance probe sealed into the top polycarbonate lid, positioned centrally and vertically down the column. All substrates in columns were slowly wetted from the bottom to gradually force all air out and to allow for uniform absorption of water. The substrates in the columns were allowed to saturate and establish equilibrium for at least 12 hours. Upon saturation, columns were allowed to drain freely by gravity (0 KPa), reaching container capacity. Thereafter, positive gas pressure was applied and monitored with a digital pressure gauge (GE Druck DPI 104) and adjusted by a gas pressure regulator (E12 244D) at the following increments: 1, 2, 4, 6, 8, 10, 20, 40, 60, 80, and 100 kPa. After allowing the leachate to stop and the column equilibrate for at least 3 hours, the volume of water leached at each pressure increment was measured for each replicate column (n=10). The capacitance data were continuously measured over the duration of each run using a Campbell Scientific CR23X micrologger and a modified datalogger program. Regression curves for the expressed water were used to predict the substrate water content values and compare them against mV output from the sensors. Upon completion of the desorption run (at 100 kPa), final volumetric water was recorded (VW), substrates in 4 randomly selected columns were removed and weighed (WW), then dried at 60 C for 96 hours and re-weighed to determine dry weight (DW). Container Capacity (CC) or the water contained in the substrate after saturation and drainage was calculated as:
CC = [(WW-DW) + VW].

Results and Discussion: ***Readily-****Available Water and Progressively Unavailable Water*. Table 1 shows the distribution of available water into RAW which in turn is typically subdivided into easy-available water (EAW) and water buffering capacity (WBC) [3]. Surprisingly, our data reveal there was little difference between the CC of the two pine bark substrates and peat. With coir and perlite, both substrates had lower CC compared to the other three substrates, and also substantially lower WBC. Pine bark ***A*** also exhibited low WBC. Overall, we were surprised to note the relatively high percentage of PUW for these substrates, indicating the small RAW fraction, and hence the importance of monitoring water content closely for precise irrigation scheduling. The variability of the capacitance sensors was very low in perlite (Fig 1A), but higher in pine bark (Fig 2A), perhaps influenced by differences in particle size. However when regression curves were fitted to the sensor data and overlaid on the real VW data (Fig 1B, 2B), the fitted curves precisely matched each other in each substrate. Note that for predictive purposes, the VWC regression should be used for monitoring and control purposes (boxes, Fig 1B, 2B). We are therefore confident that capacitance sensors can provide precise measurements of RAW, at tensions between 0 and 10 kPa in the soilless substrates that we tested.

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Table 1. Mean (n=4) bulk density (BD), container capacity (CC), easily-available water (EAW), water buffering capacity (WBC) and progressively unavailable water (PUW) in five commercial soilless substrates.

		Sphagnum peat moss	Pine bark Mix *A*	Pine bark Mix *B*	Coir (Coconut fiber)	Perlite
BD	**$g.cm^{-3}$**	0.100	0.137	0.161	0.070	0.100
CC	**mL**	1605	1498	1475	1099	1014
	Pressure (KPa)	**Distribution of Water (%)**				
EAW	1 to 5	**27**	23	20	28	18
WBC	5 to 10	**10**	4	10	1	2
—	10 to 100	**7**	2	5	1	1
UW	> 100	**56**	71	65	70	79

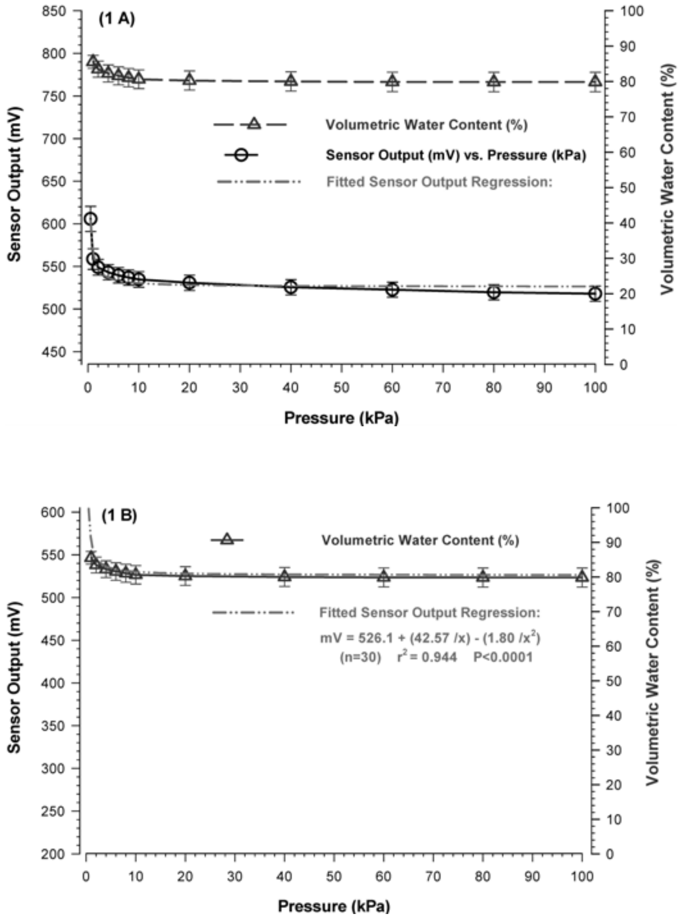

Fig. 1 Simultaneous water desorption and capacitance sensor output curves vs. pressure applied on substrate from 0 – 100 kPa positive pressure (1 A), and the fitted output regression curve vs. actual volumetric water expressed at each pressure (1 B) for perlite.

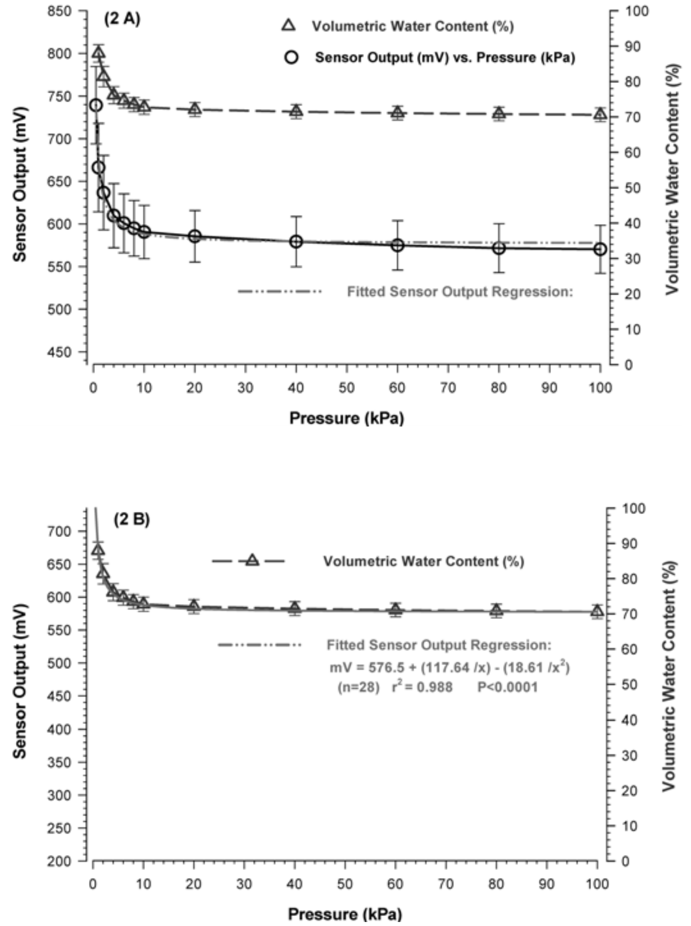

Fig. 2 Simultaneous water desorption and capacitance sensor output curves vs. pressure applied on substrate from 0 - 100 kPa positive pressure (2 A), and the fitted output regression curve vs. actual volumetric water expressed at each pressure (2 B) for pine bark mix ***A.***