Generating Water Release Curves with Simultaneous Time Domain Reflectometry Calibration in Soilless Container Media

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Nature of Work: Horticultural substrates have large pore spaces compared to many soils, low water holding capacity, and a low range of easily available water for optimum plant growth. Water that is easily available to plants can be generalized based on matric potential (tension, suction pressure) of the substrate. Horticultural media generally have water easily available in the range from 0 to -10 KPa (KPa = 10^{-3} MPa), with the major volume of water available in the free pore space up to a tension of –5 KPa . Water release curves follow a characteristic shape, yet are offset based on adsorptive qualities of the particles in the media. For example, sand will absorb no water within the particle, holding water only in pore spaces and on particle surfaces, and will be essentially dry at matric potentials approaching –10 KPa. Peat moss and pine bark on the other hand, will absorb water within the particle and on charged surfaces, making a fixed percentage of total moisture content unavailable for plant uptake. Peat moss in general exhibits characteristics of unavailable bound and hygroscopic water near 30% volumetric water content.

Water release curve data can be used to improve the precision of irrigation applications, if a method for accurately predicting water content in soilless substrates is available. This can benefit producers by maximizing plant growth in optimal moisture ranges, while minimizing leaching volumes. Time Domain Reflectometry (TDR), a promising technique, can be used to monitor moisture in containers, quantifying volumetric water content based on the apparent dielectric constant of the substrate . TDR sensors can be manufactured to match container height, and calibrated to specific substrates. TDR can be used to schedule cyclic irrigation based on the average water content measured over the height of the container; this improves irrigation precision, maintains optimum plant growth, and minimizes leaching due to excessive irrigation volume .

Materials and Methods: Four soilless substrates were selected (Premier Pro-Mix 'BX', a commercial Pine Bark Mix, Perlite, and Quikrete Sieved Washed Sand as uniform control) on the basis of their prevalence in the container nursery industry and/or their differences in particle type. Particle size analysis was conducted at the North Carolina horticultural substrates laboratory (Table 1). Desorption curves were generated for each substrate with simultaneous TDR calibration using a modified tension table and positive applied pressure (= suction pressure). Ten independent replicate columns were desorbed for each substrate. Columns were 19.5 cm tall x 12.6 cm diameter (packed uniformly to the top) to represent the height of a substrate column in a #3 production (3 gallon) container. Each sealed column had a TDR sensor fixed in the top lid, with three 18 cm wave-guides positioned centrally vertical down the column. All columns were slowly wetted from the bottom to gradually force all air out of the substrates and to allow particle adsorption of water, and establish equilibrium. Upon saturation with known volumes of water, columns were allowed to drain freely by gravity (0 KPa), until leaching finished, determining container capacity. Positive pressure was then applied step-wise in increments of 1 KPa (0 - 10 KPa) and thereafter in 10 KPa increments to 60 KPa. Allowing forced leaching to finish and equilibrium to be established, the volume of water leached at each incremental pressure was measured for each replicate (n = 10), and the TDR output for each column measured. This quantified moisture content and sensor accuracy in the range of easily available water . TDR measurements were taken using a Tektronix 1502C metallic cable tester connected to a multiplexed Campbell Scientific data logger (Logan, UT). Upon completion of desorption, column substrates were weighed wet and re-weighed dry to verify absolute moisture content. The mean moisture content and TDR output (1/Vp = 1/Velocity of Propagation) at the various matric potentials are shown graphically with standard errors.

Results and Discussion: All water release curves were nearly asymptotic beyond a -10 KPa matric potential. This implies a limited range of easily available water in horticultural substrates for optimum plant growth. Pro-mix, pine bark mix, perlite, and sand were nearly asymptotic at respective water contents of approximately 36%, 24%, 27%, and 10%. This range of moisture content (suction beyond -10 KPa) represents hygroscopic and adsorbed water, which is unavailable for optimal plant growth. Horticultural substrates have easily available water up to –10 KPa; this is the range with significant volumes of water free in the large pore spaces. Soils, in contrast, have more water available in small and medium pore spaces, and is available across a broader range of pressure potentials. Therefore, irrigation scheduling should attempt to maintain moisture content at pressure between 0 and –10 KPa for optimal plant growth. Volumetric water content will vary at these pressures based on container height and substrate characteristics such as particle size distribution and particle type.

In all substrates, TDR output followed the curve of available water. TDR standard errors at each pressure potential were less than 2% of their respective mean, and generally less than the standard error associated with the volumetric moisture content at that pressure. TDR output CV's for all pressure potentials were averaged for each substrate as an overall assesment of variability: Pro-mix=3.94, pine bark mix=3.98, perlite=4.72, sand=2.65. Thus TDR appears to have a high degree of precision for measuring water content in a diverse range of horticultural substrates.

Significance to Industry: These results provide data to substantiate the range of easily available water in soilless substrates for optimum plant growth. Substrate curves are of similar shape, determined by matric potential of the substrate, and differ based on adsorptive qualities and pore space of each substrate affecting volumetric water content. Water release curves can be used in conjunction with TDR sensors to improve cyclic irrigation application precision (automated initiation and termination) that minimize leaching fractions, yet maintain optimal plant growth rates.

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Table 1: Particle Size Distribution (% weight)

Substrate	(>6.3mm)	(6.3mm to 2.0mm)	(2.0mm to 0.5mm)	(<0.5mm)	Bulk Density
Pro-Mix 'BX'	2.4	63.9	21.5	12.2	0.11
Pine Bark Mix	3.3	35.1	35.2	26.4	0.33
Perlite	0.0	55.2	26.4	18.3	0.13
Quikrete Sand	0.0	0.4	10.7	88.9	1.38