A Pragmatic Approach to Wettability and Hydration of Horticultural Substrates

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Abstract

Moisture retention has been a key property in substrate analysis for many years. This work explores the relationship between wettability and hydration using a low cost, practical system. Hydration curves and maximum hydration were used to determine three indexes: HE 1 (initial hydration), HE 3 (a watered-in value) and HE 10 (comparing irrigated vs maximum values). Coir, pine bark and sand at 45% moisture and wetting agent reached maximum values with one hydration. However, both coir and peat captured less than half their max in initial hydration when initial moisture was reduced to 30%. Values obtained with this method numerically described common behaviors of substrates, moisture content and wetting agents.

INTRODUCTION

Many production practices are being reexamined to insure that they better fit with an overall sustainable process. Irrigation efficiency and water conservation is one such area. Part of this effort should be the examination of substrates for their ability to capture and retain the irrigation water delivered to them. The more efficient these mixes, the less water wasted. Hydration of substrates has been studied for wettability (Michel et al., 2001; Urrestarazu et al., 2007; Levesque and Dinel, 1977; Bilderback and Lorscheider, 1997) and capacity (Handreck and Black, 1984; Puustjarvi, 1974; Milks et al., 1989; Wallach et al., 1992). Both areas are vital to hydration, but neither completely describes the effect of an irrigation event on water capture and retention. The purpose of this work is to expand the description of water capture and retention. This process needs to be described in all substrates, so the procedure should be practical, simple and economical for all levels of investigation.

The approach was to perform an irrigation event and determine the water content of the substrate. By performing repeated events, one could develop a hydration curve. This would show how quickly a substrate captured the water applied as well as the quantity. By itself, this information is valuable, but the efficiency of water uptake can only be measured against a capacity or maximum value that the substrate could hold. Therefore this work developed a process to determine the rate of uptake and compared it to maximum uptake values. Since water uptake is greatly affected by water content and degree of hydrophobicity, substrate treatments included these parameters.

MATERIALS AND METHODS

The equipment for the hydration unit consisted of a transparent cylinder, 5 diameter x 15 cm height, with a mesh screen on the bottom; a 100 ml plastic vial (4 cm dia); a 250 ml separatory funnel; and a 250 ml beaker on the bottom (Fig. 1). The vial was fitted with a large O ring and placed in the top the transparent cylinder. The O ring allowed for exact positioning of the vial above the substrate surface to control hydraulic head. The vial had 5 holes in the bottom and acted as a diffuser for the force of the water as it contacted the substrate. Water went from the funnel through the diffuser, into the substrate and out to the beaker.

The flow of water was controlled at 2-3 liters per hour with the funnel stopcock. The water dripped evenly from the five holes in the diffuser onto the substrate. If ponding occurred, hydraulic head was kept to 1 to 2 cm. A hydration event used 200 ml water through the substrate with the above conditions. Any water effluent going through the substrate was recorded and the moisture retained was calculated by subtraction. Ten hydration events were performed on each substrate with 4 replications per treatment.

Materials tested were coir pith (Densu Coir, Canada), peat moss (Premier Tech, Canada), composted pine bark (Pacific Organics, NC), and sand (Builder's grade, NC). All substrates were tested at three moisture contents, both with and without wetting agent. Wetting agent was AquaGro-L at 187 ml/m^3. Samples were moistened to 1.5 mass wetness (MW), then air dried down to 0.82, 0.43, and 0.18 MW, representing moisture contents of 45, 30 and 15% by weight. These levels were too high for sand and it was wetted and dried to 15, 10 and 5% moisture.

Cylinders were filled and firmed to 200 ml of sample and packed to specific target densities for each material. All replications within a substrate treatment were packed to within 5% by weight. As substrate heights changed in the process, heights were recorded at three points on each surface and averaged. The diffuser prevented much unevenness of the substrate surfaces.

Maximum hydration was measured in a similar fashion as container capacity. After 10 hydrations, the sample cylinder was removed from the hydration unit, weighed and placed into a Buchner funnel with holes as described in the NCSU Porometer Manual (Fonteno, 2010). Water was slowly added from the bottom in a stepwise manner until it reached the top of the substrate surface. After 15 minutes, the water was drained from the sample, allowed to drain for 30 minutes then weighed. Samples were then placed in a forced-air drying oven at 105°C for 24-48 h until dry.

Water retention was used to create hydration curves and expressed as a percent age of the total volume. Hydration efficiency was expressed as the percent volume container water compared to the maximum water content it could hold. Efficiency was examined at three points. Initial hydration (HE 1) was the water held after the first hydration event divided by the maximum hydration. HE 3 was the water held after the third hydration event divided by the max. This was considered the "watered-in" level – a level that is reached after hydrating a substrate for production. HE 10 was the water content held after the tenth hydration event divided by the max. This was used to determine if the substrate ever reached the maximum hydration by irrigation.

The experiment was a completely randomized design. Statistical mean separation was done with LSD (p 0.05) using SAS (Cary, North Carolina).

RESULTS AND DISCUSSION

Hydration curves for coir are shown in Figure 2. Water retention is displayed as percent volume of substrate. For comparison, the moisture contents of 15, 30 and 45% by weight are displayed as 2, 4 and 7% by volume at 0 hydrations. The coir without wetting agent hydrated quickly at the first hydration to over 60% by volume and took up little water afterward. At 30% initial moisture, the uptake was much less (20%) and only increased in 8 to 10% increments with each additional hydration. At 15% initial moisture, the coir took up even less water and never reached the levels of the 30 and 45% treatments. Maximum values for 30 and 45% were the same (~70%) while the 15% treatment was significantly less. With wetting agent, the wetting curve response was similar at 45% moisture although slightly higher. However, both the 15 and 30% treatments reached similar maximum levels. Maximum values for all coir treatments were the same, except for the 15% without wetting agent (Table 1).

Peat without wetting agent took up much less water than the coir treatments at 45 and 30% (Fig. 3). The 15% treatment of peat was too hydrophobic to take up water consistently and the data is not shown. With wetting agent, peat took up water similarly to coir with wetting agent at 45% moisture. However, the peat at 30 and 15% took up much smaller amounts at each hydration and never reached maximum hydration.

Pine bark reached maximum hydrations by the third hydration event in all treatments except the 15% moisture without wetting agent. Sand wet up to maximum levels at the first hydration with all treatments (Curves for pine bark and sand not shown).

Using the values from the hydration curves, four specific values were calculated to measure hydration efficiency (Table 1). HE 1, HE 3 and HE 10 were calculated comparing the water retention at hydrations 1, 3 and 10 divided by the maximum hydration. The values were decimal equivalents with 1.00 being the greatest achievable. This produced values that showed how quickly (or if) a substrate reached its maximum water content. The sooner max was reached, the more efficient the substrate at capturing water.

Initial hydration (HE 1) for coir, pine bark and sand reached the maximum when the substrate had wetting agent and 45% initial moisture (0.95, 0.99, 1.00, respectively). All substrates reached the maximum at HE 3 with wetting agent and 45% moisture. Without wetting agent, only coir and sand reached maximum hydration at initial hydration (HE 1). By HE 3, coir, pine bark and sand had reached maximum without wetting agent. All substrates reached maximum values via irrigation (HE 10) with wetting agent and 45% moisture. However, only sand reached maximum at 15% moisture and no wetting agent.

These efficiency values (HE 1, 3, 10) describe the different levels of hydration obtained from drip irrigation. For example, both coir and peat hydrate well with one watering at high moisture and wetting agent (HE 1). However, at 30% initial moisture, coir took up less than half and peat less than one fifth as much water, even with wetting agent. Quick and complete hydration of substrates is essential for plants to produce good root systems. Inefficient mixes lead to more frequent irrigations and overwatering of new transplants. These values show if and where improvements need to be made to achieve this goal.

Using the data from this procedure (Table 1), we may make the following observations about the behavior of water capture and retention in these materials. First, sand had no trouble hydrating to its maximum potential under all conditions. Wet or dry, with or without wetting agent, sand absorbed to capacity every time. Pine bark had max capacity values similar to sand; however, moisture content and wetting agent changed the number of irrigations needed to reach capacity. Pine bark hydrated to capacity within three irrigations under all conditions, except the driest of conditions (15% moisture, no wetting agent). However, under these drier conditions, pine bark did not reach its max hydration level. Coir had the highest maximum hydration levels of all materials tested. The number of hydrations needed to reach this maximum increased as moisture content went down. The wetting agent produced a faster hydration with fewer irrigation events. Coir is known for its ability to hydrate well and quickly. However, it took up little water when dry and without wetting agent. Wettability with coir is still affected by these conditions, unlike sand that hydrated every time. Peat was the most affected by moisture content and wetting agent. Although peat had a high capacity to hold water, it was very hydrophobic when dry and with no wetting agent. The combination of water addition and wetting agent increased water retention in incremental steps. Peat only reached its max hydration level at 45% moisture with wetting agent. These data would indicate that the peat sample used in this study may have been more hydrophobic and captured less water than would be considered normal for sphagnum peat. This would also indicate that the wetting agent concentration needed for this particular peat may need to be higher than was used in this study to achieve water capture and retention norms.

This procedure is simple and cost effective. Materials can be tested in their natural form, without grinding or other alteration. The equipment is not expensive and can be done almost anywhere. The hydration procedure takes less than two hours. However, if a specific moisture content is desired for testing, the air drying of these materials could take from one to four days, depending on the level needed.

For this study we chose hydrations 1, 3 and 10 to use as efficiency indicators. However, any and all hydrations can be used to describe water capture. The hydration curve is extremely useful in visually describing water capture. However, the HE indexes show particular comparisons that proved useful.

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Tables

Table 1. Hydration values for four substrate components.

Substrate	Moisture content (g/g)	WA	Db (g/cc)		HE 1		HE 3		HE 10		Max. hydration (% volume)	
Coir	45	yes	0.08	c	0.95	a	1.00	a	1.00	a	74.1%	a
Coir	30	yes	0.08	c	0.43	b	0.82	b	0.98	a	71.6%	a
Coir	15	yes	0.10	b	0.29	c	0.61	c	0.99	a	73.9%	a
Coir	45	no	0.08	c	0.89	a	0.99	a	0.99	a	69.6%	a
Coir	30	no	0.09	d	0.29	c	0.59	c	0.88	b	71.8%	a
Coir	15	no	0.10	a	0.21	c	0.46	d	0.85	b	64.3%	b
Peat	45	yes	0.12	a	0.76	a	1.00	a	1.00	a	70.4%	a
Peat	30	yes	0.13	b	0.19	bc	0.42	b	0.78	b	71.2%	a
Peat	15	yes	0.14	c	0.15	c	0.26	c	0.58	c	62.2%	c
Peat	45	no	0.11	a	0.23	b	0.39	b	0.81	b	68.4%	a
Peat	30	no	0.13	b	0.19	bc	0.27	c	0.56	c	50.9%	b
Pine Bark	45	yes	0.19	e	0.99	a	1.00	a	1.00	a	38.0%	a
Pine Bark	30	yes	0.20	d	0.85	b	1.00	a	1.00	a	37.1%	a
Pine Bark	15	yes	0.24	b	0.50	d	0.94	a	1.00	a	39.0%	a
Pine Bark	45	no	0.19	e	0.93	b	1.00	a	0.97	a	38.8%	a
Pine Bark	30	no	0.22	c	0.68	c	1.00	a	0.96	a	36.5%	a
Pine Bark	15	no	0.25	a	0.41	d	0.78	b	0.88	b	37.4%	a
Sand	15	yes	1.39	a	1.00	a	1.00	a	0.95	a	37.2%	abc
Sand	10	yes	1.46	a	1.00	a	1.00	a	1.00	a	36.5%	abc
Sand	5	yes	1.43	a	1.00	a	1.00	a	1.00	a	38.8%	bc
Sand	15	no	1.45	a	1.00	a	1.00	a	1.00	a	37.0%	ab
Sand	10	no	1.31	a	1.00	a	1.00	a	1.00	a	40.7%	bc
Sand	5	no	1.34	a	1.00	a	1.00	a	1.00	A	38.9%	bc

WA = Wetting agent = AquaGro-L at 187 ml/m^3.
*LSD (p 0.05) letters separate treatments within a column and within a substrate.

Figures

Fig. 1. Hydration unit setup for testing with four replications.

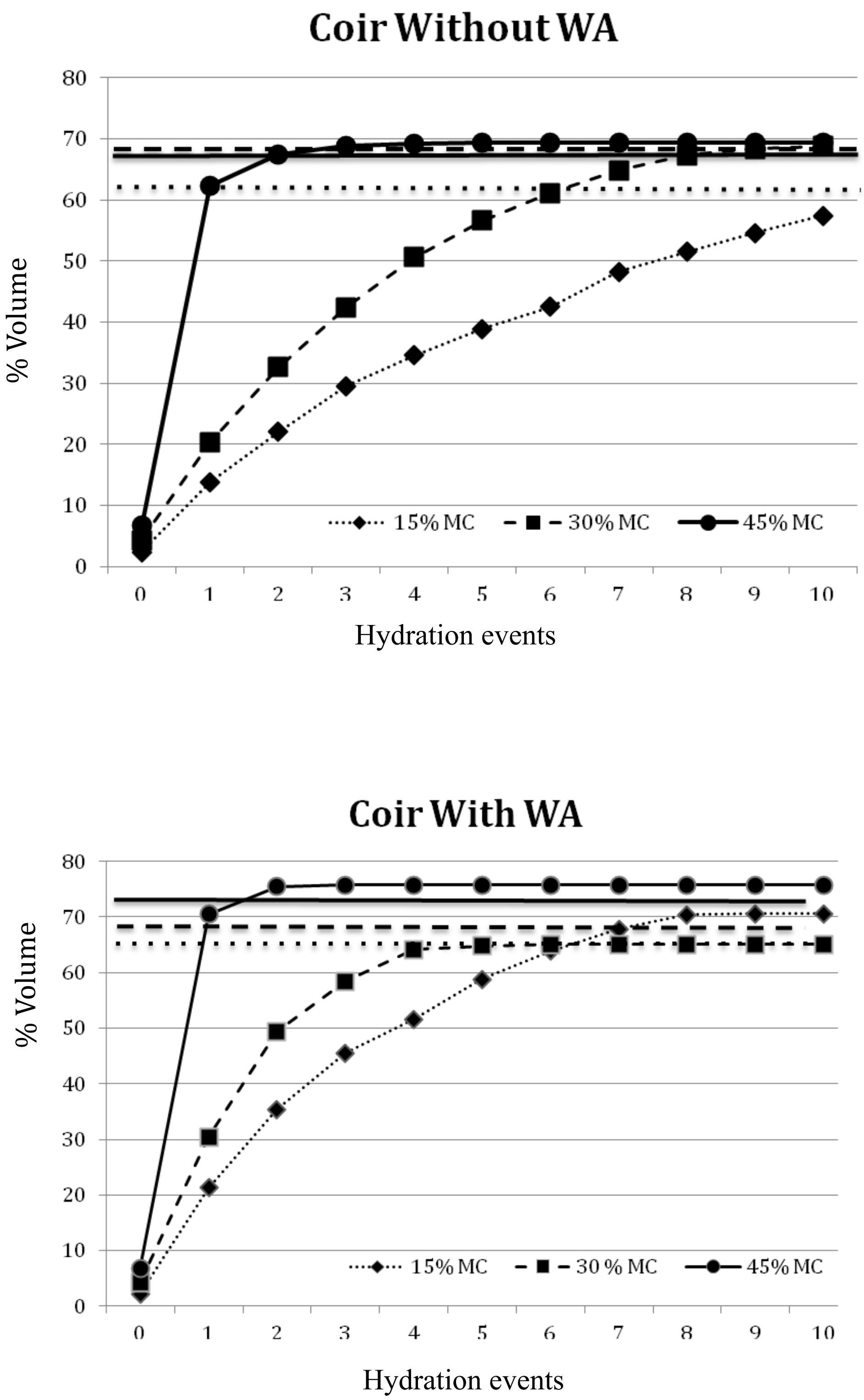
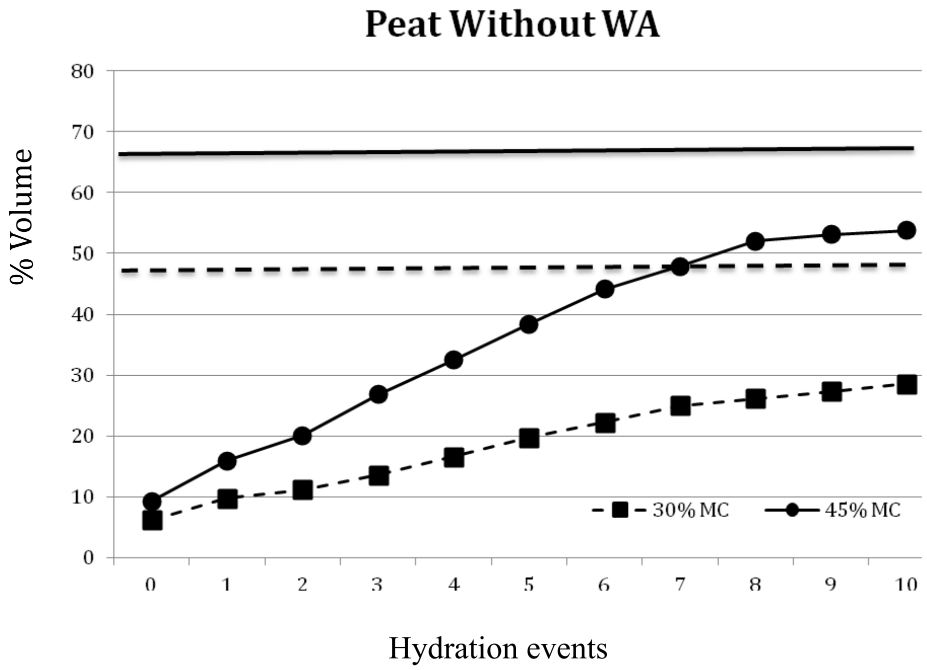


Fig. 2. Top: Coir pith, no wetting agent. Bottom: coir pith with wetting agent. Solid and dashed horizontal lines are maximum water content values.



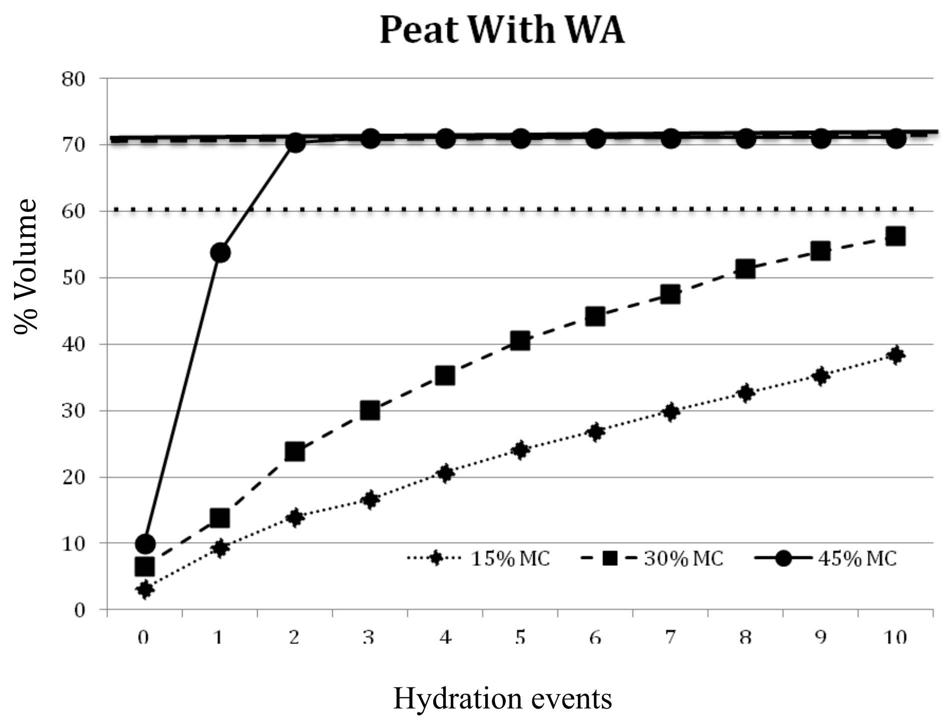


Fig. 3. Top: Peat moss, no wetting agent. Bottom: Peat moss with wetting agent. Solid and dashed horizontal lines are maximum water content values.