The use of coir for reducing risks of peat-based substrate hydrophobicity

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Abstract

The wettability of peat, coir and peat:coir mixes (90:10, 80:20 and 70:30 v v^{-1}) were analyzed from contact angle measurements and hydration efficiency tests, and also compared to the effects of wetting agents. Results showed a change from a hydrophilic to an increasing hydrophobic character of peat in relation to the intensity of drying, whereas coir remained hydrophilic. Although its influence is lower than those measured with wetting agent, coir addition in peat-based substrates improved the ability to rewet (i.e. to reduce the risks of hydrophobicity occurring during drying).

Keywords: wettability, hydration efficiency, water retention, contact angle

INTRODUCTION

Hydrophobicity occurring during drying is well known to reduce the ability to capture and retain water of many peat-based substrates (Michel, 2010). The use of synthetic wetting agents (surfactants) is commonly practiced to reduce these risks, thereby avoiding potential negative impacts for plant growth. Over the last few years, some professional substrate companies have also been testing the addition of coconut coir to peat-based mixes as a means to improve wettability without the use of synthetic surfactants.

The aim of this work was to quantify and compare the wettability and hydration efficiency of peat, coconut coir, both with or without wetting agent addition, and peat:coir mixes.

MATERIALS AND METHODS

Samples and preparation

Experiments were carried out on a 0-25 mm Irish white milled peat, a 4-7 mm coconut coir fraction coming from Sri Lanka (both supplied by Dumona company based in Sauméjan, France), and 90:10, 80:20 and 70:30 vol. peat:coir mixes. Wettability and rehydration efficiency were analyzed on these substrates with or without wetting agent. The wetting agent, Fertil N°10® (provided by Fertil company based in Boulogne-Billancourt, France) was incorporated in substrates with the recommended concentration of 200 mL of wetting agent by cubic meter of substrate.

Prior to the experiments, the samples were equilibrated at two initial moisture contents expressed in weight (MC): 33 and 50% w w^{-1}. Table 1 outlined the relationship between initial moisture content (MC) and volumetric water content (VWC) for each material, and their dry bulk densities as well. Wettability and rehydration efficiency were thus evaluated by both methods on these substrate components and mixes, prepared at these two initial moisture contents.

Methods for measuring wettability

1. Contact angle measurement.

Contact angles were measured by the capillary rise method described by Michel et al.

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(2001). The method consisted of following the capillary rise on a column of substrates with water by using a Krüss Processor Tensiometer K12®. The speed of capillary rise, translated by the increase in weight of the sample, is measured in relation to time by the computer, and the contact angle was determined from the following Washburn's Equation (1921):

$$\cos\theta = \frac{m^2}{t}\frac{\eta}{\rho^2 \gamma_L c}$$

where θ is the contact angle (°), *m* is the mass of the adsorbed liquid (g), *t* is the time (s), η, ρ, γ_L are the viscosity (mPa s), the density (g cm^{-3}) and the surface tension of the liquid (mJ m^{-2}), respectively, and *c* corresponds to an empirical constant of the porosity and tortuosity of the capillaries, which depends on particle size and degree of packing.

The parameter c was initially assessed by using a liquid with a very low surface tension (i.e. hexane) which completely wets the sample (θ=0). The contact angles with water could then be calculated and the wettability estimated, knowing that the greater the contact angle, the more the hydrophilicity decreases or the hydrophobicity increases. However, when the material is too hydrophobic (contact angles ≥90°), there is no capillary rise, and the degree of hydrophobicity can then not be estimated. Contact angle measurements were carried out on a small quantity of materials (~5 cm^3) with six replicates per liquid (hexane then water) for a given MC and for each substrate tested.

2. Rehydration efficiency test.

Rehydration efficiency was measured using the method described by Fields et al. (2014). A 200 cm^3 substrate sample was homogeneously packed in a 10 cm height cylinder (with the objective of having the same bulk density – given in Table 1 – for a same material whatever the moisture content), then placed in the hydration efficiency unit. The substrate column was then subjected to six successive hydration events which involved passing 200 mL water through each sample and to collect effluent as it came out the bottom, from which cumulative water content retained (from WC_1=water capture after one hydration event to WC_6=water capture after 6 hydration events) in the substrate is calculated. After these six hydration events, the substrate column was saturated from the bottom then drained in order to determine container capacity (CC) of each material. Four replicates per moisture content and per substrate were analyzed for these measurements. For the analysis of these results, the moisture contents, expressed in weight (w w^{-1}) for the preparation of the materials were translated in VWC (v v^{-1}). Correspondence between initial moisture contents (MC, in weight) and volumetric water contents (WC, v v^{-1}) were given in Table 1. For example, MC=33% and MC=50% w w^{-1} represented WC=0.07 and WC=0.14 v $v^{-1}$for the white peat; 0.05 and 0.10 v v^{-1} for coir, respectively.

Table 1. Relationship between initial moisture contents expressed in weight (MC) and volumetric water contents (WC_0) for tested substrates.

Substrates	Bulk density (g cm^{-3})	Initial water content WC_0 (v v^{-1}) for both contact angle measurements and hydration efficiency tests	
		33%	50%
		Initial moisture content MC (w w^{-1})	
White peat	0.14	0.07	0.14
Mixes	0.13	0.06	0.13
Coir	0.10	0.05	0.10

RESULTS

Contact angle measurements (Table 2)

As already presented by Michel (2015), contact angles increased (i.e. wettability decreased) with the intensity of drying. However, at a similar MC, contact angles were lower for coir than for peat. Coir showed contact angles lower than 90° for both MC (84.3 and 69.5° for MC=33 and 50%, respectively) and then could be considered as hydrophilic, whatever the intensity of drying. Conversely, peat exhibited hydrophobicity for MC=33% (contact angle=90° means that there was no capillary rise), and became partly hydrophilic for MC=50% (89.4°). The addition of 20% coir to peat-based substrate improved the hydrophilic behavior of the mix for both MC tested (87.8° for MC=50% but also 89.0° for MC=33%).

Table 2. Contact angles (°) measured for some tested substrates, prepared at 33 and 50% moisture contents (w w^{-1}) with or without wetting agent addition (90°≥no capillary rise).

Substrates	- Wetting agent		+ Wetting agent Fertil N°10®	
	MC=33% w w^{-1}	MC=50% w w^{-1}	MC=33% w w^{-1}	MC=50% w w^{-1}
White peat	90.0°	89.4°	89.6°	81.4°
Coir	84.3°	69.5°	74.7°	50.3°
80:20 white peat: coir	89.0°	87.8°	84.5°	80.6°

Wetting agent addition systematically led to a decrease in contact angles for peat, coir, and mixes, thus improving their wettability. All of them remained hydrophilic with wetting agent addition, whatever the intensity of drying tested.

Hydration efficiency tests

As shown for contact angle measurements, hydration efficiency depended on the intensity of drying, but also differed depending on tested substrates.

Coir recovered VWC close to its CC_{MAX} (0.36 v v^{-1}) after only two and four hydration events, with WC_2=0.34 v v^{-1} for MC=50% and WC_4=0.32 v v^{-1} for MC=33%. Furthermore, $CC_{[33]}$, $CC_{[50]}$ and CC_{MAX} were not significant different (Table 3; Figure 1), indicating that CC were not influenced by the intensity of drying and consequently that coir recovered its ability to rewet. This result is in agreement with contact angles measurements, and confirmed that coir maintained a hydrophilic character during drying (at least, up to MC=33%).

Table 3. Water contents WC_1 and WC_6 (% v v^{-1}) measured after 1 and 6 hydration events and container capacities $CC_{[33]}$ and $CC_{[50]}$ for substrates prepared at 33 and 50% moisture contents. CC_{MAX} (% v v^{-1}) corresponds to the container capacity for non-dried substrates.

Substrates	CC_{MAX} (% v v^{-1})	MC=33% w w^{-1}			MC=50% w w^{-1}		
		WC_1	WC_6 (% v v^{-1})	$CC_{[33]}$	WC_1	WC_6 (% v v^{-1})	$CC_{[50]}$
White peat	0.69	0.09	0.15	0.47	0.24	0.40	0.60
90:10 white peat:coir	0.67	0.10	0.19	0.54	0.24	0.48	0.67
80:20 white peat:coir	0.64	0.11	0.22	0.52	0.27	0.50	0.64
70:30 white peat:coir	0.61	0.14	0.27	0.52	0.39	0.52	0.61
Coir	0.36	0.20	0.33	0.33	0.31	0.36	0.36
White peat + wetting agent Fertil N°10®	0.69	0.12	0.30	0.67	0.63	0.68	0.69
Coir + wetting agent Fertil N°10®	0.36	0.30	0.34	0.35	0.31	0.36	0.36

For peat, both water capture and CC decreased with the intensity of drying. The VWC after a first rehydration event (WC_1) reached 0.24 v v^{-1} and 0.09 v v^{-1} and slowly increased up to 0.40 v v^{-1} and 0.15 v v^{-1} after 6 hydration events (WC_6) for MC=50 and 33%, respectively (Table 3). CC changed from 0.60 v v^{-1} for $CC_{[50]}$ to 0.47 v v^{-1} for $CC_{[33]}$ (Figure 1), and were also quite lower than CC_{MAX} (0.69 v v^{-1}) (Table 3). These results clearly reflected an increasing hydrophobicity for peat in relation with the intensity of drying.

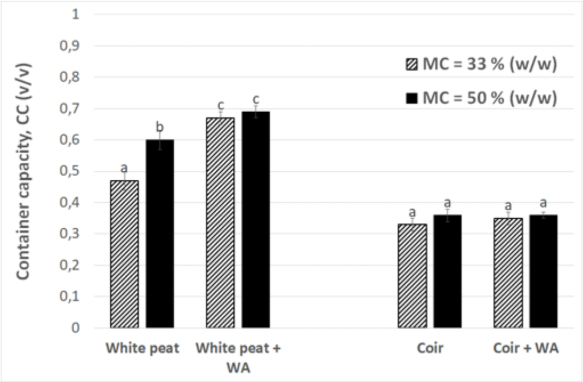

Figure 1. Container capacity $CC_{[33]}$ and $CC_{[50]}$ for white peat and coir initially prepared at 33% and 50% moisture contents, with or without wetting agent addition.

Wetting agent addition in substrates always led to reductions in hydrophobicity, so that it increased the water capture (from WC_1 to WC_6) and both $CC_{[33]}$ and $CC_{[50]}$ of peat, and also improved the water capture for coir from 0.20 to 0.30 v v^{-1} in the first hydration event (WC_1) (Table 3). Thus, wetting agent addition helped coir and peat to quickly rewet (WC_1 close to CC_{MAX}), except for peat at the lower initial moisture content (MC=33%) where WC_6 remained lower than CC_{MAX}, but $CC_{[33]}$ significantly increased (0.67 v v^{-1} with wetting agent) and then became close to CC_{MAX} (0.69 v v^{-1}).

Knowing that water retention properties of mixes vary depending on the proportions of peat and coir, the effect of coir addition in the rehydration efficiency of peat-based mixes was analyzed by comparing the evolutions of CC/CC_{MAX} ratios (Figure 2) and of WC_X/CC_{MAX} ratios (with X=number of hydration events) (Figure 3) obtained for peat, coir and mixes for MC=33% and MC=50%. Results showed a significant increase in $CC_{[33]}$ and $CC_{[50]}$ (Table 3) and then in $CC_{[33]}/CC_{MAX}$ and $CC_{[50]}/CC_{MAX}$ (Figure 2) from 10% vol. coir addition compared to pure peat. These CC/CC_{MAX} ratios changed from 68% for pure peat to 81 to 85% for mixes for MC=33% and reached 100% for all mixes (compared to 87% for pure peat) for MC=50%. More, the water captures significantly increased with the proportion of coir in the mixes (see the example of WC_3/CC_{MAX} presented in Figure 3).

DISCUSSION AND CONCLUSIONS

Although its water capture (WC/CC_{MAX}) decreased with the intensity of drying (Figure 3), coir can be considered as a hydrophilic material, recovering its maximum water retention properties after drying ($CC_{[33]}$ and $CC_{[50]}$ close to CC_{MAX}). Conversely, white peat exhibits an increasing hydrophobic character in relation to the degree of drying, with lower both water capture and CC. This difference in water affinity described from the hydration efficiency tests for coir and white peat is moreover confirmed by contact angle measurements, as Michel et al. (2017) already compared on other substrates.

Coir addition in peat-based mixes significantly increases the ability to rewet. The higher the proportion of coir in the mixes, the easier the rehydration of the mixes, as shown by the increases of both WC/CC_{MAX} and CC/CC_{MAX} in relation with the proportion of coir (10% of coir is however sufficient to reach a fully rehydration ($CC_{[50]}/CC_{MAX}$=100%) of the mix for MC=50%).

The influence of coir vs wetting agent addition was determined from CC/CC_{MAX} and WC_X/CC_{MAX} ratios. In driest conditions (MC=33%), similar water captures after 3 hydration events were observed for both 80:20 and 70:30 peat:coir mixes and pure peat with wetting agent (WC_3/CC_{MAX} close to 30%), but the CC/CC_{MAX} ratios remained lower for peat:coir mixes than for pure peat with wetting agent. For MC=50%, peat:coir mixes and pure peat with wetting agent were fully rewetted, but the water capture was higher for peat with wetting agent than for mixes.

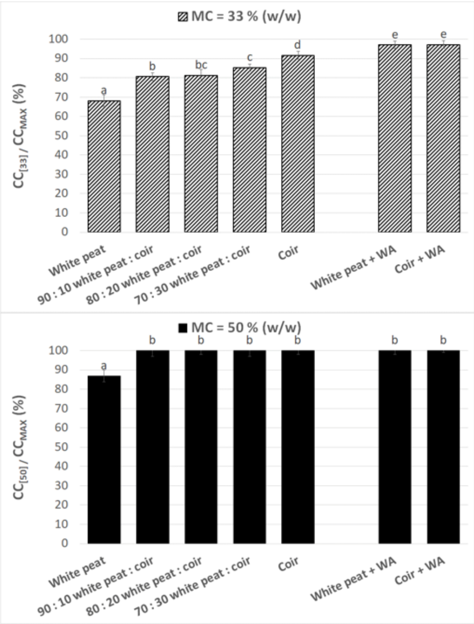

Figure 2. Ability to rewet of substrates estimated from the $CC_{[33]}/CC_{MAX}$ and $CC_{[50]}/CC_{MAX}$ ratios according to their initial 33% (striped bars) and 50% (solid bars) moisture contents.

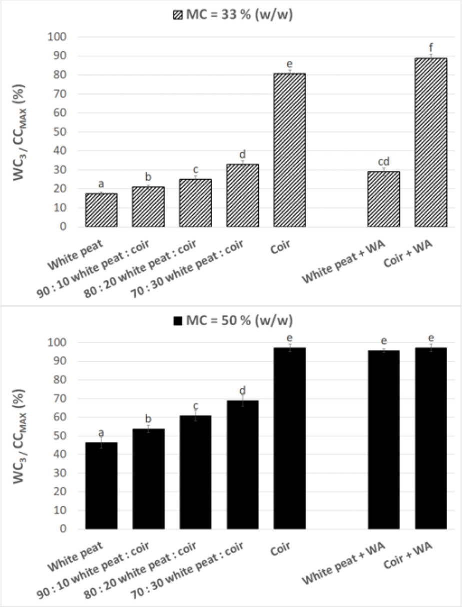

Figure 3. Water captures after 3 hydration events estimated from the WC_3/CC_{MAX} ratios according to their initial 33% (striped bars) and 50% (solid bars) moisture contents.

The whole of these observations conclude that coir is quite hydrophilic, in opposition to peat becoming more and more hydrophobic with the intensity of drying. The risks of peat-based substrates' hydrophobicity are then reduced by an increasing proportion of coir in the mixes. Although its influence is lower than those of wetting agents, coir addition is then beneficial for the ability to rewet peat-based mixes.

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