Comparison of the Physical Properties of Vermicompost from Paper Mill Sludge and Green Compost as Substitutes for Peat-Based Potting Media

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Abstract

The properties of vermicompost, green compost, and their mixes as substitutes for peat were evaluated regarding their recommendation for potting media. The mixes with a maximum of 50% of vermicompost or green compost had acceptable air filled porosity (AFP) and easily available water (EAW). In the vermicompost the level of organic matter (OM), dry bulk density (DBD) and shrinkage were acceptable; however, the AFP and EAW together were not at the recommended level in the different batches; as a consequence, vermicompost should not be used alone for potting media. In the green compost, the level of OM was low which increased the DBD and consequently the AFP was diminished. The particle size distribution (PSD) was different among peat, vermicompost and green compost. The coarse peat had the lower proportion of particles from 0.25 to 2.00 mm (41%) whereas the green compost had the lower coarseness index (CI: percentage by weight of particles larger than 0.5 mm in diameter), 48.4%. The direct effect of the PSD, OM and DBD in the water and air availability was confirmed. Moreover, there were high correlations between the OM, DBD, shrinkage, pore volume and PSD with the water release curve. Those properties should be considered in order to increase the level of substitution of vermicompost in peat-based potting media.

INTRODUCTION

The substitution of peat in potting mixes by compost may be limited by the characteristics of the compost. The addition of compost affects bulk density, porosity, water holding capacity and air space (Atiyeh et al., 2001; Hidalgo and Harkess, 2002). The particle size of the components for potting media affects bulk density (Noguera et al., 2003) and shrinkage (Burés et al., 1993). Moreover, there are fractions of particle sizes that increase the air content, and others the water content in the mixes (Verdonck and Demeyer, 2004). The relationships among physical properties of components of substrates with the air and water availability have been helpful to determine their optimal proportion for potting media (Burés et al., 1988; Fernandez and Corá, 2004; Zamora et al., 2005).

This study aimed to relate the physical properties of vermicompost, green compost and peat in mixes for potting media, and to define the relations between these properties that determine the air and water availability. Thus, part of the peat in potting mixes might be substituted by the vermicompost and green compost.

MATERIALS AND METHODS

The dry bulk density (DBD), shrinkage, organic matter content (OM), particle size distribution (PSD), water release curve, rewetting rate and moisture content of vermicompost, green waste, white peat fractionated in coarse and fine were determined in three repetitions according with the European Standards, EN 13041 (European Committee for Standardization, 1999).

The vermicompost was derived mainly from paper mill sludge and apple waste, the green compost from pruning and the peat was a milled Baltic white peat. There were

four batches of vermicompost from different enterprises. These materials were mixed in various ratios. In order to compare vermicompost and green compost, ten to 90% of peat-based medium was replaced by vermicompost batch A or green compost (GC) in relation with fine peat: coarse peat, in the following ratios: 1:8:1, 1:3:1, 3:4:3, 2:1:2, 1:0:1, 1.5:0:1, 7:0:3, 4:0:1, 9:0:1. To have another set of mixtures with small, medium and high level of vermicompost, the proportion in the mixes of vermicompost batches B, C and D were 25, 50 and 75% (vermicompost: fine peat: coarse peat 0.44:1:0.31, 1:0:1, 3:0:1). The characteristics of the components and mixes were evaluated considering the recommendations for potting media (RPM). Data of the coarse peat is not given because it was out of the RPM). The relationships of the properties were analysed by ANOVA, correlations and estimation of parameters by linear regressions, with the Genstat 9th, 2007 software. Particle size distribution was determined by weight with several mesh widths (Aendekerk et al., 2000). Based on the fractions remained in the various mesh width (MW), several parameters were calculated such as coarseness index (CI: percentage by weight of particles larger than 0.5 mm in diameter) (Noguera et al., 2003), MW 5 to 16 mm, the proportion of particles between 0.25 to 2.0 mm (PP 0.25-2.0), recommended for potting media (Abad et al., 2001), the proportion of particles ≤ than 2 mm (PP≤2), MW 2 to 0 mm, and ≥2 mm (PP≥2), MW 2 to 16 mm.

RESULTS

The characteristics of the fine peat fell within the recommendations for potting media. The mixes with less than 50% of vermicompost or green compost had acceptable air filled porosity (AFP) and easily available water (EAW) (Table 1). In the vermicompost the level of OM, DBD and shrinkage were acceptable (Table 2). However, the AFP and EAW together were not at the recommended level in the vermicompost batches (Table 1). In the vermicompost and green compost the rewetting rates were higher in the first minutes than the fine peat (Table 2).

The PSD was different among peat, vermicompost and green compost i.e. coarse peat had the lowest PP 0.25-2, whereas, the green compost had the lowest coarseness index CI, which implied lower air availability i.e. low AFP and water at -10 cm suction (Fig. 1 and Table 2). There were some good correlations between the OM, DBD, pore volume, shrinkage and PSD with points of the water release curve (Table 3). Also, a high negative correlation was found between the OM and the DBD, which was negatively correlated with the moisture content and pore volume (Table 3).

Furthermore, DBD, EAW, AFP, pore volume, moisture and shrinkage were estimated by linear regression as a function of the PSD, OM and DBD (Table 4). In the vermicompost, the OM and shrinkage were highly correlated with the parameters of PSD (Table 3), which were different for the batches of vermicompost (Table 5). Moreover, the shrinkage showed a good correlation with the AFP as it has been shown in mixes with peat and perlite (Heiskanen, 1995).

DISCUSSION

The characteristics of the vermicompost from paper mill sludge and apple waste limited the level to which it may substitute peat. The large PP 0.25-2 mm in vermicompost decreased the EAW in the mixes (Table 4). On the other hand, the AFP was increased at the same time as the shrinkage which had a high negative correlation with the PP≤2 (Tables 2 and 3).

In the green compost the level of OM was low, which increased the DBD. It was negatively affected by the CI (Table 4). As a consequence, the AFP was lower than required (Table 2); AFP showed a correlation with the DBD of -0.93. Moreover, the CI has been shown to be positively correlated with the air content (Abad et al., 2001).

The OM was negatively correlated with the PP 0.25-2 (Table 3). Because of this, the increase of vermicompost in the peat-based media caused a decrease in the easily available water which in turn increased the air filled porosity (Fig. 2).

The OM in the vermicompost had also a negative correlation with the CI and

PP≤2 but positive with the PP≥2 (Table 3). OM is responsible for the aggregation of particles (Puget et al., 2000). Consequently, the type and content of the OM affected the characteristics of the components and thus the mixes for potting media.

The mathematical models gotten by linear regression may be used to select mixes with the required AFP and EAW for the specific plant requirement in potting media, basing on PSD, DBD and OM (Table 4). Also, Fernandez and Cora (2004) simulated air and water relationships based on BD.

CONCLUSIONS

Based on the physical properties, vermicompost or green compost should not be used by themselves but only in mixes with peat like materials up to levels not exceeding 50%. Furthermore the selection of mixtures of vermicompost and peat may be based on the relationships between organic matter, particle size distribution and dry bulk density which give a fair prediction of the water and air availability.

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Tables

Table 1. Air filled porosity and easily available water in mixes with vermicompost and green compost.

% of vermicompost in the mix	Air filled porosity (%)	Easily available water (%)	% of green compost in the mix	Air filled porosity (%)	Easily available water (%)
BATCH A					
10	13	31	10	11	33
20	14	30	20	11	32
30	18	23	30	11	29
40	18	22	40	9	27
50	18	18	50	11	23
60	22	16	60	9	22
70	21	18	70	8	20
80	21	15	80	7	18
90	23	15	90	7	16
100	22	15	100	7	17
BATCH B					
25	12	29			
50	16	20			
75	10	20			
100	9	18			
BATCH C					
25	10	31			
50	11	27			
75	9	23			
100	8	20			
BATCH D					
25	11	29			
50	18	20			
75	14	14			
100	10	19			

Table 2. Physical properties of the components and the recommended ranges (RR) for potting media.

Property	RR[z]	Vermicompost average	Green compost	Fine peat
Organic matter (% w/w)	> 40	57ab	28b	99a
Dry bulk density (kg/m^3)	60-250	244ab	500a	83b
Shrinkage (% v/v)	< 37	36a	26a	28a
Pore volume (% v/v)	85-95	87b	77c	95a
Moisture % v/v at delivery	> 40[y]	63a	42a	60a
Easily available water[x] (% v/v)	25-35	18b	17b	33a
Air filled porosity[w]	10-30[t]	12a	7a	13a
Moisture % v/v container capacity	60-100[s]	80ab	74b	87a
Moisture % v/v suction - 10 cm	55-80	68a	68a	74a
Moisture % v/v suction - 31.6 cm	-	53a	56a	48a
Moisture % v/v suction - 50 cm	31-40[r]	50a	51a	41a
Air % v/v container capacity	-	8a	3b	8a
Air % v/v suction - 10 cm	15-40	20a	10a	21a
Air % v/v suction - 31.6 cm	-	34ab	22b	47a
Air % v/v suction - 50 cm	-	38ab	26b	53a
Rewetting rate after 1 min. (%)	-	4.38b	9.04a	1.18c
Rewetting rate after 4 min. (%)	-	19.01a	17.81a	5.88a
Rewetting rate after 8 min. (%)	-	31.06a	23.62a	31.4a
Rewetting rate after 15 min. (%)	-	42.23a	30.97a	31.4a

[z]For ebb & flow growing system, not sensitive plants to air or drought (Aendekerk et al., 2000).
[y]Sullivan and Miller, 2005.
[x]Difference between -10 and -50 cm of suction for water.
[w]Difference between 0 and -10 cm of suction for air (Plaza and Lao, 2006).
[t]Ballester-Olmos, 1992 cited by Plaza and Lao, 2006.
[s]Abad et al., 2001.
[r]Noguera et al., 2003.
Same letters in same row are significant similar.

Table 3. Correlations between the physical properties of vermicompost, green compost, peat and their mixes for potting media.

Property	Particles in the mesh widths			Coarseness Index	Shrinkage	Dry bulk density	Pore volume[z]	Organic matter
	0.25-2.0 mm	≤2 mm	≥2.0 mm					
Moisture at delivery			0.51	0.79 0.84[y]	0.67[z]	-0.66	0.64	0.69
Pore volume	-0.79[z]	-0.58	0.63	-0.62[z]		-1.00		0.90 -0.99[y]
Easily available water	-0.62[y]			-0.74[z]		-0.52[y]		
Water volume at container capacity				-0.56[z]		-0.74 -0.84[y]	0.86	
Water at -10 cm suction	-0.57[y]				0.54			
Water at -31.6 cm suction			0.55		0.75 0.96[z]	0.60[y]	-0.62	-0.56
Water at -50 cm suction				0.60[z]	0.96[z]	0.54		-0.61
Air at container capacity		-0.70	0.64	0.68[y]		0.55	0.73	0.57
Air filled porosity				0.51[y]	-0.76[z] 0.94[x]			
Air at -10 cm suction		-0.51	0.51	0.57	-0.55 -0.81[z]			0.56
Air at -31.6 cm suction		-0.57	0.57		-0.53 -0.92[z]	-0.90[y]	0.91	0.80
Air at -50 cm suction		-0.57			-0.86[z]	-0.77 -0.91	0.93	0.81
Dry bulk density		0.57	-0.64	-0.56[y]				-0.90
Organic matter	-0.64[x] -0.86[w] -0.58[t]	-0.54 -0.80[x]	0.63 0.88[x]	-0.63			0.89	
Shrinkage	-0.78[x]	-0.71[x]	0.54[x]					

[z]In mixes with vermicompost (all batches).
[y]In mixes from 10-100% of substitution level.
[x]In vermicompost (all batches).
[w]In mixes with vermicompost A.
[t]In mixes with green compost.
Note: numbers without superscript refers to all mixtures and components.

Table 4. Linear regressions based on organic matter (OM), particle size distribution[z] and dry bulk density (DBD) from all mixtures and all components.

Property	R^2	Standard error	Function
Dry bulk density	86.7	39.5	= -587-3.54OM-15.65CI+21PP≥2 +21.6PP 0.25-2
Easily available water	91.6	1.73	= 123.5-0.04DBD+1.6CI-1.80PP≥2 -3.1PP0.25- 2+1.1PP≤2-0.2OM
Air filled porosity	89.3	1.61	=-92.9-0.7DBD-2.9CI+3.0PP≥2+5PP 0.25-2 -1.4PP≤2+0.1OM
Pore volume	99.9	0.11	=103.1-0.04DBD-0.06CI+0.06PP 0.25-2 -0.05PP≤2
Moisture	94.8	1.88	=26.3+0.04DBD+2.5CI-3.2PP 0.25-2+1.4PP≤2 -1.7PP≥2+0.2OM
Shrinkage	93.5	1.21	=-89.4+0.06DBD+3.4CI-3.1PP≥2-5.1PP 0.25-2 +1.7PP≤2-0.1OM

[z]Based on the fractions remained in the mesh widths.
CI: coarseness index; PPS≤2: proportion of particles ≤2 mm; PPS≥2: proportion of particles ≥2 mm; PP 0.25-2: proportion of particles between 0.25 to 2 mm.

Table 5. ANOVA for the parameters of particle size distribution[z], shrinkage and organic matter content in vermicompost batches.

Property	Significance level	LSD	Vermicompost batch			
			A	B	C	D
Coarseness index	***	2.2	83	88	85	84
Proportion of particles between 0.25-2.0 mm	***	3.2	88	77	78	70
Proportion of particles ≥2.0 mm	***	6.4	21	33	28	54
Proportion of particles ≤2.0 mm	***	7.5	94	81	82	67
Organic matter content	***	2.6	52	47	55	79
Shrinkage	***	2.5	27	36	42	39
Air filled porosity	***	0.8	22	9	8	10

[z]Based on the fractions remained in the mesh widths.
NS: not significance difference.
***: At the 0.1% probability level.
LSD: Lower significance difference.

Figures

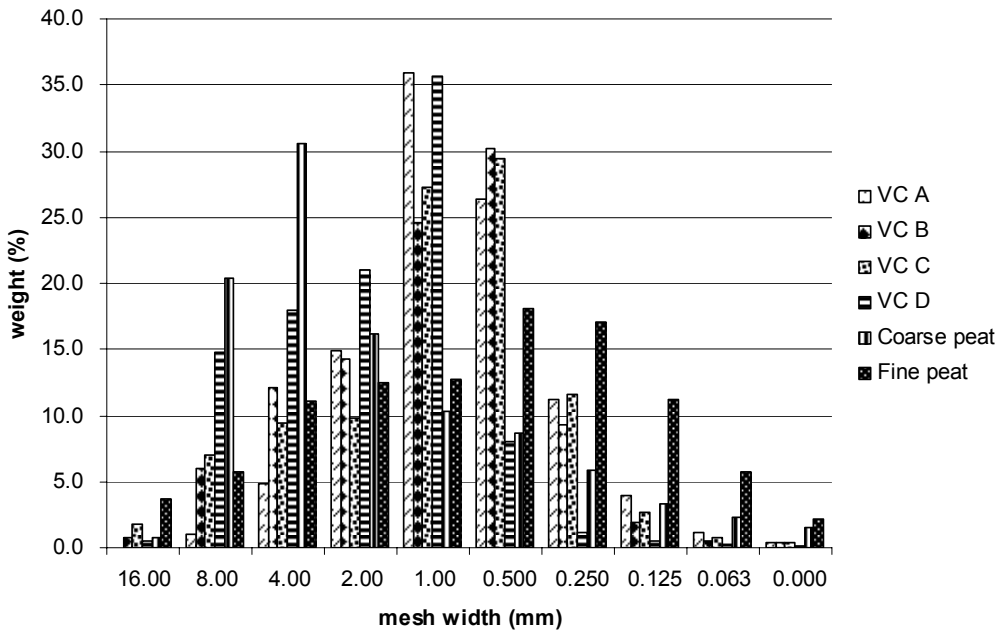

Fig. 1. Particle size distribution of the vermicompost (VC) batches A, B, C and D, coarse and fine peat.

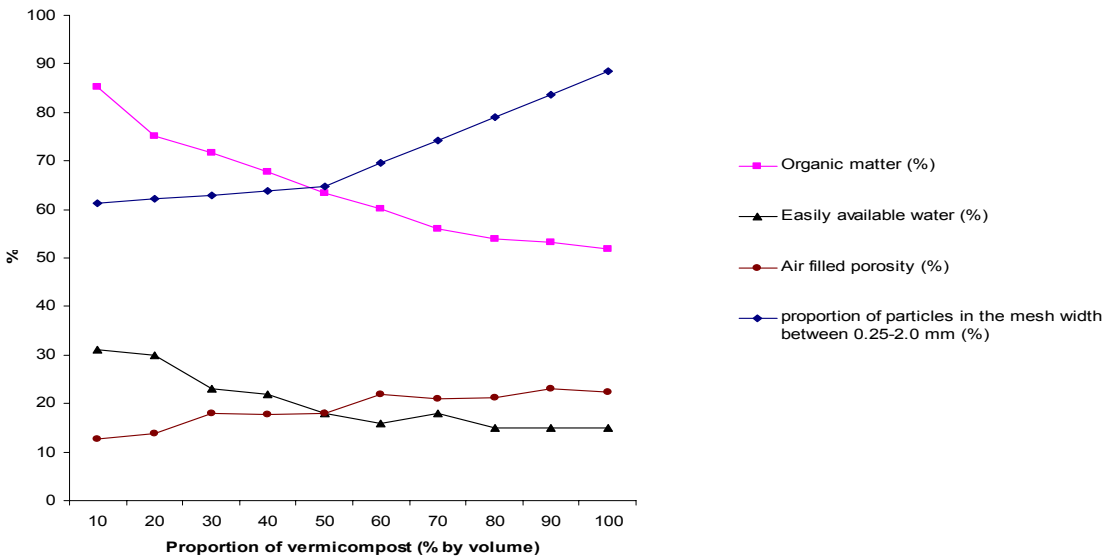

Fig. 2. Effect of the substitution level of vermicompost (batch A) in the peat-based media in the organic matter, proportion of particles in the mesh width between 0.25-2.0 mm, air filled porosity and easily available water.