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Testing composted bamboo residues with and without added effective microorganisms as a renewable alternative to peat in horticultural production

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ABSTRACT

This study assesses the potential for composted bamboo residues to serve as a renewable replacement for peat in horticultural growing media. Bamboo residues and wheat bran compost (ratio 90:10) were prepared in two batches, with (B1) and without (B2) effective microorganisms, and mixed with peat at 25%, 50%, 75%, and 100% by volume. Both batches were then used in greenhouse tests with two horticultural plants, *Osmanthus fragrans* (Thunb.) Lour. and *Hydrangea macrophylla* (Thunb.) Ser., using pure peat as a control. Batch B1 showed higher peak temperature and longer thermophilic phase than B2 during composting, and had higher N but lower total C and C/N ratio than B2. The addition of either batch to the growth media increased bulk density, particle density, and air space compared with pure peat, but decreased total pore space and total water-holding capacity. At lower compost content, the physical and chemical properties of the test batches were very similar to those of an ideal substrate, especially those mixed with B1. Plants grown in media mixed with B1 (25% or 50%) or B2 (25%) showed no significant differences in growth rates for height and ground diameter compared to those of the pure peat control. The results suggest that using effective microorganisms can increase mineralization during composting of bamboo residues, and that composted bamboo residues should be considered as a component of horticultural growth media in partial substitution for costly and less sustainable peat.

1. Introduction

Bamboo is a group more than 1200 woody perennial evergreen plant species of the grass family Gramineae, distributed mainly in tropical and subtropical areas (Song et al., 2013). Bamboo has many advantages over other woody plants, such as fast growth, high production, and high ecological value (Scurlock et al., 2000; Yen, 2016; Zhou et al., 2005). Many studies have shown that bamboo can rapidly accumulate large biomass (Shanmughavel et al., 2001; Yen, 2016), suggesting high potential for carbon storage. Some bamboo species are widely cultivated and utilized in Asia, Africa, and South and Central America for furniture, construction materials, and food. However, overall forest coverage in tropical and subtropical areas has declined drastically in the past decade, although bamboo coverage has increased by nearly 10% to more than 24 million hectares worldwide (Zhou et al., 2005). However, due to some specific characteristics of bamboo culm and limitations in processing technology, more than 50% of harvested bamboo timber is discarded as residues when processed (Zhang and Liu, 2011). Many processors simply dispose of these residues directly into the environment, due to their high water content and low caloric value; this causes massive waste of natural resources and also damages the local environment (Flynn et al., 2017). Therefore, developing new ways to utilize bamboo-processing residues could be of great economic and ecologic value.

Peat is extensively utilized as a potting substrate in horticultural nurseries because of its desirable physical, chemical, and microbiological properties along with high water retention capacity (Baddi et al., 2004). However, recent years have seen increased the environmental concerns over the rapid depletion of peat, due to the associated destruction of endangered wetland ecosystems and resulting reduction in soil carbon sequestration (Abad et al., 2005). Therefore, the study of recycled peat alternatives has become an important topic in horticultural research (Sarkar et al., 2016; Tiquia et al., 2002). There is currently an international effort to evaluate various organic substrates as alternatives to peat for the planting substrate of potting mixes (Goyal et al., 2005). Composting is a bio-oxidative aerobic process in which a succession of different microbial populations (Parkinson et al., 2004) degrades the original organic substrates into a more physically and chemically stable product; the resulting product may provide a more sustainable alternative to peat (Aleandri et al., 2015). Compost has

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many advantages as an ingredient in growing media including nutritional contributions, positive impacts on soil microbiota, and suppression of soil-borne diseases (Benito et al., 2003; Bugbee, 2002; Castillo et al., 2013; Ventorino et al., 2016). Potential limitations include high bulk density, low water-holding capacity, residual phytotoxicity, and unsuitable salinity and pH (Raviv, 2009). Additionally, the effects of compost can vary depending on the parent materials and composting process, making difficult the generalizations (Benito et al., 2003; Morales-Corts et al., 2014; Rainbow, 2007). The success of the composting process and the usefulness of the resulting compost as an organic amendment are determined by microbial activity (Benito et al., 2009; Goyal et al. 2005). Effective microorganisms (EMs) are mixtures of beneficial microorganisms (Fan et al., 2017). They are composed of five families, ten genera and more than 80 types of aerobic and anaerobic microbes including photosynthetic bacteria, lactic acid bacteria, yeast, Actinomycetes, fungi and so on (Ahn et al., 2014). Many studies have shown that EMs can be applied as inoculants to increase the microbial activities and diversity of agricultural wastes (Iranzo et al., 2004). The addition of EMs during composting can provide a cost-effective biological method of treating different types of organic wastes (Fan et al., 2017; Jusoh et al., 2013). However, to date, there are no reports on composting of bamboo residues using EMs to accelerate the composting process and increased nutrients.

Therefore, the aim of this study was to assess the feasibility of using bamboo residues as a partial peat substitute in horticultural growth media by to evaluate the composting process (with or without addition of EMs) through chemical and physical analysis of compost, and to assess the compost's potential as a partial peat replacement in potting soil, by observing the growth parameters of plants grown in different mixes.

2. Materials and methods

2.1. Composting process and sampling

Moso bamboo residues (*Phyllostachys pubescens*) from a bamboo-processing factory in Anji, China, were used as the main component for composting. To prevent pathogenic infection, the bamboo poles were processed within three days after felling, and only healthy bamboo poles were chosen and processed to make bamboo panels (Jiang et al., 2002). Due to the initial C/N ratio of the residues (> 200, Table 1) was too high to properly initiate microbial activities, wheat bran was used to adjust the C/N ratio (Stevenson et al., 2012). The residues were then ground to < 3 mm in preparation for the composting process, which was conducted in a shaded area under a roof using a mixture of 90% bamboo residues and 10% wheat bran formed into trapezoidal piles about 1.5 m high with a 2 × 3 m base; each pile weighed approximately 2000 kg.

To test the role of EMs in compost production, commercial EMs from Tongxiang (Jiannong Biotech. Co., Ltd., China), were added to three piles (B1) while leaving another three untreated (B2). These are a mixed culture of microorganisms including predominant populations of lactic acid bacteria and yeasts with smaller numbers of photosynthetic bacteria, Actinomycetes, and other types of microorganisms (Ahn et al., 2014). In order to activate the EMs, one part EMs microbial inoculant and one part molasses were mixed with 20 parts chlorine-free water. This solution was then stored for three to five days in an air-tight expandable container for fermentation; built-up gas was released once daily. The B1 piles were then inoculated by adding a 10% EMs solution constituting 20% of the total water added to a given pile. Water was then added to each pile until the moisture content reached 60–65% (wet basis).

When the piles were fully built and mixed, they were covered with plastic sheets in order to retain moisture and prevent excessive heat loss. The moisture content was maintained at 45–55% throughout the process by frequently checking the piles and adding water when needed. All piles were composted for 60 days, being turned at 5-day intervals to maintain porosity and ensure proper aeration. The temperature was measured at 2-day intervals with a digital thermometer at 20 cm depths.

After 60 days, samples were taken from the ends of the piles and analyzed to determine changes in the physical and chemical properties resulting from the composting process (as described in Section 2.3). Each sample was divided in half: one portion was set aside for analysis of physical properties, while the other was dried to a constant weight (60 °C for two days), ground in a mortar to pass through a 2 mm sieve, and stored in screw-capped glass bottles for chemical analysis.

2.2. Plant growth trials

The growth trial was conducted at a commercial nursery in Linan, Zhejiang, China to test the compost's feasibility as a potential replacement for peat in growth media. Both compost batches (B1 and B2) were mechanically mixed at four proportions (25%, 50%, 75%, and 100% by volume) with peat, and pure peat used as a control; the peat was a weakly decomposed sphagnum moss (Klasmann-Deilmann GmbH, Germany) with particle diameters of 0–5 mm and no previous fertilization.

Small seedlings of *Osmanthus fragrans* (Thunb.) Lour. and *Hydrangea macrophylla* (Thunb.) Ser. were used as horticultural test species, with each transplanted into 3 L plastic pots containing 2.5 L of media. All treatments were arranged in a completely randomized design with five replicates (30 seedlings each) under greenhouse conditions at a temperature of 20–25 °C with 15 h light and 9 h dark per day. The plants were irrigated twice weekly by means of a sprinkler system, but no fertilizer was applied. At the end of the three-month growth period, the height and ground diameter of all plants were measured.

2.3. Physical-chemical analyses

The physical properties of the different growing media, including bulk density (BD), particle density (PD), total pore space (TPS), air space (AS), and total water holding capacity (TWHC) were determined using procedures described by Spomer (1990); the coarseness index (CI), expressed as the weight percentage of particles with size > 1 mm, was determined according to Richards et al. (1986). The dry matter content of each media was determined by drying at 105 °C for 12 h. Electrical conductivity (EC) and pH were measured in a solution of 1:5

Table 1
Different chemical properties at the beginning and end of the composting process.

Treatment	pH	EC (ds/m)	TOC (%)	TN (g/kg)	C/N	P (g/kg)	K (g/kg)	Ca (g/kg)	Mg (g/kg)
BR	5.38a	0.72a	47.3a	2.1a	225.2a	0.13a	0.58a	0.22a	0.11a
BRW	5.44a	0.74a	46.1a	4.3b	107.2b	0.17b	0.56a	0.26b	0.10a
B1	6.02b	0.91b	36.3b	4.9d	74.1c	0.18b	0.64b	0.31c	0.13a
B2	5.78b	0.88b	39.3c	4.5b	87.3d	0.16b	0.61b	0.31c	0.11a

BR: Bamboo residues; BRW: 90% BR + 10% wheat bran; B1: BRW composted with effective microorganisms (EMs); B2: BRW composted without EMs. Values are means (n = 5). Different letters in the same column mean significant differences according to the LSD test at $p < 0.05$.