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Evaluation of Spent Mushroom Compost as a Container Medium for Production of Seedlings of Two Oak Species

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ABSTRACT

Seven media amended with 30% to 75% (by volume) of spent mushroom compost (SMC) were trialed on two oak tree species to evaluate the possibility of using SMC for oak tree container seedling production by comparing the physical and chemical properties of media and assessing the plant growth of oak seedlings. The high electrical conductivity and pH of media amended with SMC decreased quickly by leaching. Seedling quality index of *Quercus aliena* decreased as the proportion of SMC increased in the media. Only the media with 50% or less SMC yielded seedlings similar to or better than the control. However, for *Q. virginiana*, all media except that without perlite gave similar or better quality seedlings than the control. Nitrogen, phosphorus and potassium contents of shoot were significantly increased in both species grown on SMC amended media, except the nitrogen of *Q. virginiana*. No visual symptoms of nutrient deficiency or toxicity were observed. In conclusion, in container seedling production, SMC can be used with perlite as a peat substitute up to 75% for the salt tolerant *Q. virginiana*, and 50% for *Q. aliena*.

INTRODUCTION

Peat is the most widely used material as a major component of growing media for containerized plant production (Bunt 1988). However, environmental concerns regarding peat harvesting have influenced the horticultural industry toward the wise use of peat and sustainable growing media (Carlile & Coules 2013). The conservation of peat resources has been recently emphasized in China in reference to the preservation of wetland ecosystems (Meng 2006). Most good quality horticultural grade peat is extracted from northeastern China with transportation accounting for nearly half the cost for users outside this area. Imported peat from Northern Europe and Canada has recently become more expensive and variable in quality. The need for the horticultural industry to source good quality and locally available low cost peat substitutes has been emphasized for many years. Many recycled organic materials including sawdust, green compost, spent mushroom compost and cowpeat have been studied and used for many years as peat substitute components of growing media (Li et al. 2009).

Of these recycled organic materials, spent mushroom compost (SMC), the remains of the substrate in which mushrooms are produced, is available in large quantities where mushrooms are grown. It is estimated that about 5 kg of SMC is produced for each kilogram of mushrooms (Williams et al. 2001). The annual production of edible fungi in China reached 25.7 million tons in 2011 (Wu et al. 2013), therefore more than 1 billion tons of SMC is discarded. SMC has already been researched and used in horticulture as a component of container media for many decades (Henny 1979, Chong & Rinker 1994). The uniformity of physical and chemical properties of SMC is very important to be considered as good quality plant growth media. Though there is great variability between pH, EC or nutrient content among various SMCs from different mushroom species and farms, it is possible to provide SMCs with a year-round uniformity from the same farm and species (Jordan et al. 2008, Kwack et al. 2012).

The EC values of SMC ranged from 4.9 to 8.3 $dS{\cdot}m^{-1}$, while the pH ranged from 7.6 to 8.2 (Chong 2005). These values exceeded the threshold EC of 1.0 $dS{\cdot}m^{-1}$ and desirable pH 5.5 to 7.0 for general nursery plant culture. Thus the percentage of SMC in the container medium is usually recommended to be no more than 50% by volume, especially for seedling production (Bunt 1988, Chong 2005). However, it is still possible to use SMC in relatively high concentrations in container media for those species tolerant to salt and high pH, especially in small containers since soluble salts can leach quickly (Chong 2005). Investigations on the use of SMC as a container medium have mainly been for vegetables, ornamental flowers and foliage plant production (Henny 1979, Chong 2005, Medina et al. 2009, Kwack et al. 2012, Zhang et al. 2012, Sendi et al. 2013, Gonani et al. 2011). There has been comparatively little research on its use for woody plants, and most of this has been on ornamental shrubs or small trees (Chong et al. 1991, Chong et al. 1994, Chong & Rinker 1994).

The objective of this study was to evaluate the possibility of using increasing ratio of SMC from the golden needle mushroom (*Flammulina velutipes*) production as media components in container seedling culture of two oak species, a deciduous *Quercus aliena*, and an evergreen *Q. virginiana*. These two species were proved tolerant to salt stress (Kurtz et al. 2013, Li et al. 2012). By assessing the physical and chemical properties of media with different proportion SMC, and assessing the oak plant quality grown on these media.

MATERIALS AND METHODS

Container media preparation: Spent mushroom compost (SMC), provided by a local mushroom farm, was wind row composted for 3 months and aged for another 6 months before the experiment. The raw material of fresh growth media for needle mushroom production is composed of 45% ground corncob, 15% cottonseed hull, and 40% rice hull. The EC of the saturated media extract of the aged SMC was 6.5 $dS \cdot m^{-1}$, pH 7.8. The oven dried SMC had total nitrogen 2.2%, phosphorus (P_2O_5) 1.8%, potassium (K_2O) 1.1% and organic matter 68%. Peat was obtained from Heilongjiang province, northeastern China. Perlite and vermiculite were horticultural grade. Different proportions of SMC were blended with other components to formulate 7 media (Table 1). A medium comprising 60% peat and 40% perlite was used as control (CK).

Plant material and experimental design: Acorns of *Q. aliena* were collected from native trees in the forest of Yunnan province in October, 2012. Acorns of *Q. virginiana* were collected from a cultivated tree at Shanghai Chenshan Botanical Garden in November, 2012. Acorns were soaked in freshwater for 2 h, after which they were collected and air dried and packed in plastic ziplock bags, and stored at a 4°C refrigerator. On 15th November the acorns were sterilized with a $5g \cdot L^{-1}$ $KMnO_4$ solution for 10 min, rinsed and sown into plug trays with 32 cells (11cm depth) using a medium composed of 80% peat and 20% perlite by volume. Trays were placed on the greenhouse bench. The bench was covered with an additional polyethylene row tunnel to keep high air humidity.

The seedlings were about 10-15 cm in height on 26th March 2013. Seedlings with uniform height and stem diameter were transplanted to 18 cm diameter × 18 cm depth round plastic pots. The pots were filled with experimental media of different compositions. Pots were arranged on greenhouse benches as a completely randomized block design with 6 blocks, each block had 4 replicates for both species. Thus, both species had 24 pots for each medium treatment. Three weeks after planting, 1.0 g of an 18N-6P_2O_5-12K_2O controlled-release fertilizer (Osmocote, 6 months) was surface applied to each pot. Plants were irrigated by hand watering three to four times a week with an average leaching fraction of 0.2.

Determination of physical and chemical properties: The initial physical properties of the substrates, including bulk density, total porosity, air-filled porosity, and water holding capacity were measured using the Australian Standard Method (Standards Australia 2003) before transplanting. A 1000 mL plastic beaker was used for bulk density and porosity measurement. During the cultivation, EC and pH of the media leachate were determined monthly using the pour-through method (Yeager et al. 1983). A saucer was placed under each container, deionized water was poured slowly onto the growth container surface and about 50 mL leachate was collected and measured by portable EC meter (SX 650) and pH meter (EXTECH pH100). Six pots of each treatment were selected from different blocks for the measurements.

Plant growth measurement: After 7 months, plants were measured and harvested before the leaves of the deciduous species, *Q. aliena* defoliated. Plant height, stem diameter (root collar) and average widths (means of the widest width and width perpendicular) of 12 plants from each treatment were measured. Shoots and roots from 6 plants of each treatment were harvested and oven dried at 85°C for 48 h. The seedling quality index was calculated according to the following formula: $QI = (TDW)/(PH/SD + SDW/RDW)$, where TDW is the total dry weight ($g \cdot plant^{-1}$), PH is the plant height (cm), SD is the stem diameter (mm), SDW is the shoot dry weight ($g \cdot plant^{-1}$) and RDW is the root dry weight ($g \cdot plant^{-1}$) (Dickson et al. 1960).

Plant macronutrients assay: The dried shoot (mix of all stems and leaves) of plant from different treatments were milled and passing through a 1 mm screen. The ground dry material (0.2000g) was wet digested by H_2SO_4-H_2O_2 solution. Nitrogen was determined by the Kjeldahl method (Horneck & Miller 1998). Ammonium was determined by distillation into boric acid (20 $g \cdot L^{-1}$) with indicator and titrated with standard 0.05 $mol \cdot L^{-1}$ HCl. Phosphorus was determined by the vanadomolybdo-phosphoric yellow colour method (Jackson 1973). Potassium was determined by

Table 1: Initial container media composition (% by volume).

Media	SMC	Peat	Perlite	Vermiculite
A	75		25	
B	60		40	
C	45		55	
D	30	30	40	
E	50		40	10
F	60	20	20	
G	60	40		
CK		60	40	

flame emission spectrophotometry (Horneck & Hanson 1998). Six replicates of each different treatment were determined.

Data analysis: All the results were subjected to analysis of variance using SPSS 19.0. Normal distribution was tested by Kolmogorov-Smirnov criterion. Where significant differences occurred, means were separated using Duncan's multiple range test at P = 0.05.

RESULTS AND DISCUSSION

Basic physical and chemical properties of media: All the media formulated with SMC were low in bulk density, while the medium G (60% SMC+40% peat) without perlite had the highest bulk density, and the medium C (45% SMC+55% perlite) which had the highest proportion of perlite had the lowest bulk density (Table 2). The bulk density of the other media did not have significant difference compared to the control. The total porosity of all the media were ranged from 83.5% to 90.4%. The air-filled porosity, increased with the proportion of perlite increasing, ranged from 10.5-21.4%, which meets the general consensus of desirable air-filled porosity (10-20%) (Bunt 1988). Both the pH and EC value of those media mixed with SMC were significantly higher than that of the control.

EC and pH changes of leachate from container media: The initial EC values of container media leachate were significantly increased with the increase of SMC. The media containing 75% SMC (A) showed the highest EC of 6.2 $dS{\cdot}m^{-1}$; EC of medium D (30% SMC) was 2.6 $dS{\cdot}m^{-1}$, the control medium without SMC was only 0.6 $dS{\cdot}m^{-1}$ (Fig. 1). However, the leachate EC values of all media containing SMC decreased significantly in the first two months then remained relatively stable. The control medium without SMC showed a slight increase in EC as nutrients were released from the controlled release fertilizer. The rapid decrease of EC indicated that the high salt contents of SMC amended media were leached effectively through regular watering. The rapid salt leaching from the container media with good drainage is the key to success of the seedling growth in media containing high amounts of SMC (Chong et al. 1991, Chong 2005). Most of the media in our experiment contained large amount of perlite, which was beneficial for rapid elimination of salts by leaching. However, it has been advised to leach SMC before use as a high proportion component of the growing medium for other salt sensitive crops (Gonani et al. 2011).

The initial pH values of all the media containing SMC were above 7.5, with the pH of media A and B above 8.0; only the control medium without SMC had a pH value less than 7.0. The pH values of all the media containing SMC decreased during the whole experimental period, due to leaching of SMC salts and the nutrients released from the controlled release fertilizer. Most of the pH values decreased to about 7.0 after 4 months growth, and to about 6.5 in the last two months (Fig. 2).

During the whole seedling growth stage, no symptoms of disorders caused by high salinity or pH were observed, even at the small seedling stage in the first month. The reason for this could due to the high tolerance to salt stress of these two species (Kurtz et al. 2013, Li et al. 2012). This was consistent with the results obtained from a wide assortment of deciduous species (Chong 2005).

Plant growth: The best seedling quality index of *Q. aliena* was found in medium C (45% SMC+55% perlite) and medium E (50% SMC+40% perlite+10% vermiculite), without significant difference with CK (Table 3). Only medium A (75% SMC) showed significantly smaller stem diameter and lighter root dry weight compared to control. Those media (A-75% SMC+25% perlite; B-60% SMC+40% perlite; F-60% SMC+20% peat+20% perlite; G-60%

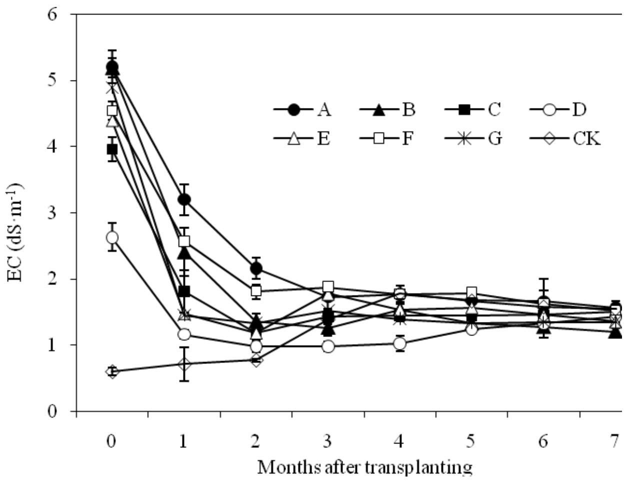

Fig. 1: Monthly changes of medium leachate electrical conductivity (EC) during seedling growth. Values represent means with standard error of 6 replicates.

Table 2: Initial physical and chemical properties of different container media.

Media	Bulk density (kg·m^{-3})	Air-filled porosity (%)	Water Holding Capacity (%)	Total Porosity (%)	pH^z	EC (dS·m^{-1})^z
A	180.3±4.5b^y	17.8±1.1ab	70.7±2.6a	88.5±4.3	8.1±0.3a	5.9±0.6a
B	173.5±3.8b	19.2±0.7a	71.2±3.2a	90.4±3.6	8.0±0.2a	5.2±0.3b
C	164.5±5.3c	21.4±1.6a	62.1±2.7b	83.5±4.2	7.9±0.3a	3.9±0.2c
D	178.4±3.8b	15.4±0.8b	73.2±3.6a	88.6±3.1	7.5±0.1a	2.6±0.3d
E	169.5±4.7bc	13.8±0.4bc	72.8±3.1a	86.6±2.5	7.8±0.2a	4.4±0.2bc
F	178.8±4.1b	13.3±0.6bc	72.4±4.2a	85.7±4.2	7.7±0.4a	4.5±0.4b
G	203.4±3.2a	10.5±0.7c	73.3±3.9a	83.8±3.8	7.4±0.3a	4.9±0.3b
CK	185.5±4.5b	19.8±1.1a	68.7±2.6a	88.5±4.3	6.9±0.3b	0.6±0.1e

^{z} pH and EC were measured in the leachate from container media by pour through method (Yeager et al. 1983).
^{y} Values represent mean±SE (n=6), any two means within a row not followed by the same letter are significantly different at $P \leq 0.05$.

Table 3: Stem diameter, plant height, canopy width, root and shoot dry weight and seedling quality index of *Q. aliena* and *Q. virginiana* seedlings in differentcontainer media.

	Stem diameter (mm)	Plant height (cm)	Canopy width (cm)	Root dry weight (g·plant^{-1})	Shoot dry weight (g·plant^{-1})	Seedling quality index^z
			Q. aliena			
A	3.93±0.20c^y	17.75±2.02c	18.94±2.62b	5.27±0.59d	3.58±0.80c	1.70±0.43c
B	5.02±0.34bc	28.67±3.69bc	20.00±1.85b	6.75±1.98cd	6.58±0.95bc	1.99±0.23c
C	6.71±0.23a	35.67±2.35ab	30.78±2.09a	13.80±0.90ab	13.45±1.18a	4.33±0.54a
D	6.27±0.29ab	44.33±3.02a	31.78±2.73a	12.28±2.11abc	13.47±0.60a	3.15±0.16b
E	6.01±0.29ab	34.67±2.26ab	30.28±1.67a	15.80±4.00a	11.25±0.60bc	4.17±0.54a
F	5.60±0.39ab	27.11±5.13bc	22.61±3.86ab	8.85±1.35bcd	10.63±1.60bc	3.22±0.25b
G	5.48±0.40ab	28.67±3.77bc	23.44±2.10ab	9.15±1.23bcd	9.05±1.83bc	2.92±0.18b
CK	6.08±0.51ab	24.89±1.02bc	28.78±1.87ab	10.98±0.92bc	9.38±0.85bc	4.11±0.26a
			Q. virginiana			
A	5.72±0.17a	77.33±4.34ab	18.44±1.33a	8.13±0.32b	12.30±0.41de	1.36±0.08ab
B	5.37±0.39a	74.00±8.16b	16.56±1.02a	7.92±0.34b	14.05±0.28cd	1.41±0.07ab
C	5.95±0.41a	93.00±8.35ab	18.50±1.35a	9.38±0.43ab	19.47±1.73a	1.63±0.11a
D	6.01±0.19a	99.33±4.26a	15.78±0.71a	10.26±0.37a	16.63±0.63b	1.48±0.05ab
E	6.00±0.23a	100.78±5.49a	17.72±0.75a	10.30±0.00a	16.22±0.94bc	1.44±0.13ab
F	6.27±0.16a	99.11±3.96a	15.39±0.84a	8.23±0.42b	15.22±0.62bc	1.33±0.03ab
G	5.74±0.23a	80.56±4.22ab	16.50±1.00a	6.00±0.43c	11.30±0.37e	1.09±0.07c
CK	5.96±0.23a	97.67±4.19a	14.56±0.67a	8.67±0.73b	13.88±0.71cd	1.25±0.09b

^{z}Seedling quality index (QI) = (TDW)/(PH/SD + SDW/RDW), where TDW is the total dry weight (g·plant^{-1}), PH is the plant height (cm), SD is the stem diameter (mm), SDW is the shoot dry weight (g·plant^{-1}) and RDW is the root dry weight (g·plant^{-1})
^{y} Values represent mean±SE (n=12 in stem diameter, plant height, and canopy width; n=6 in root dry weight, shoot dry weight and seedling quality index), any two means within a row not followed by the same letter are significantly different at $P \leq 0.05$.

Table 4: Nitrogen, phosphorus and potassium contents of *Q. aliena* and *Q. virginiana* seedling shoots (mg·g^{-1} dry weight).

	Q. aliena			*Q. virginiana*		
	N	P	K	N	P	K
A	22.42±2.16ab^z	3.89±0.44b	12.50±1.17a	10.56±0.15b	1.48±0.04a	8.85±1.25a
B	26.94±2.93a	4.18±0.25ab	8.75±1.29ab	11.18±1.10b	1.61±0.15a	4.66±0.48cde
C	22.23±2.03ab	4.76±0.29ab	6.09±0.83bc	9.18±3.42b	1.38±0.15a	3.99±0.19de
D	24.15±3.21ab	5.17±0.08a	9.72±0.59ab	10.40±2.55b	1.40±0.18a	4.45±0.10deg
E	22.46±2.29ab	4.73±0.34ab	7.24±1.30ab	14.96±1.48a	1.47±0.07a	5.92±0.21bcd
F	22.63±2.81ab	5.04±0.25a	10.06±2.08ab	10.74±3.28ab	1.40±0.09a	6.75±0.80b
G	26.92±1.00a	4.64±0.37ab	13.18±2.74a	14.00±1.85a	1.42±0.15a	6.34±0.15bc
CK	16.88±2.12c	2.53±0.16c	4.73±0.63c	12.48±1.69ab	0.78±0.05b	2.67±0.15f

^{z}Values represent mean±SE (n=6), any two means within a row not followed by the same letter are significantly different at $P \leq 0.05$.

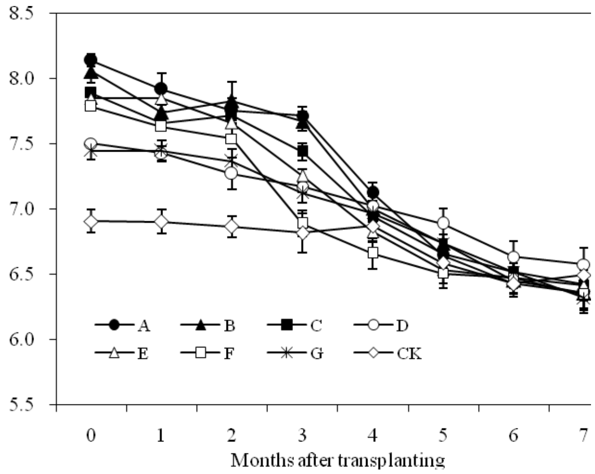

Fig. 2: Monthly changes of medium leachate pH during seedling growth. Values represent means with standard error of 6 replicates.

SMC+40% peat) containing 60% or more SMC showed significantly lower seedling quality index compared to the control. The root dry weight, shoot dry weight and seedling quality index decreased as the proportion of SMC increased in the medium.

However, the seedling quality of *Q. virginiana* in most media did not show great variation and had similar or better growth than the control, except for medium G (60% SMC+40% peat) which had lowest QI and root and shoot dry weights. The highest ratio (75%) SMC, in medium A, did not affect the growth of *Q. virginiana* compared to the control. This could be due to the fact that *Q. virginiana* seedlings are highly tolerant of salinity (Kurtz et al. 2013). Trees of this species can often be found growing in coastal areas where their roots are inundated in sea water at high tides (Williams 1998).

Macronutrient contents of seedlings grown in different media: Nitrogen, P, and K contents of *Q. aliena* shoots were significantly enhanced in all the media containing SMC (Table 4). Phosphorus and K in *Q. virginiana* were also significantly increased in all media containing SMC compared to the control. The N contents of plants from all SMC amended media had no significant difference compared to the control, though there were difference between them. The increase in the macronutrient contents in shoots could be due to the high levels of these nutrients in the SMC (Zhang et al. 2012). However, macronutrient contents did not increase in proportion with the amounts of SMC in the medium; this may be because the fertilizer rate exceeded the optimum requirement for the seedlings. There were no visual symptoms of nutrient deficiency in the control or nutrient toxicity in SMC amended media. According to the abundance of macronutrients in SMC (Bunt 1988, Kwack 2012), it is possible to reduce the fertilizer rates in these SMC amended media, or postpone the fertilizer application time to avoid salt stress when the seedlings are small.

CONCLUSIONS

Our results showed that SMC can be used as a peat substitute up to 75% in volume for the salt tolerant oak *Q. virginiana*, and 50% for *Q. aliena* container seedling production, when the media contain perlite to achieve good porosity and are irrigated to promote leaching. SMC as a peat substitute in container tree seedling production can not only be considered as a locally available and low price soilless medium for nursery production, but can also contribute to an environmentally friendly method of recycling and disposal of agricultural wastes as well as reducing the amount of peat extraction necessary and protecting sensitive environments.

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