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Research article

Composted biogas residue and spent mushroom substrate as a growth medium for tomato and pepper seedlings

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ABSTRACT

A composted material derived from biogas production residues, spent mushroom substrate (SMS) and pig manure was evaluated as a partial or total replacement for peat in growth medium for tomato and pepper seedlings. Five different substrates were tested: T1, compost + perlite (5:1, v:v); T2, compost + peat + perlite (4:1:1, v:v:v); T3, compost + peat + perlite (2.5:2.5:1, v:v:v); T4, compost + peat + perlite (1:4:1, v:v:v); and CK, a commercial peat + perlite (5:1, v:v). The physical-chemical characteristics of the various media were analyzed, and the germination rate and morphological growth were also measured. Real-time Quantitative PCR (qPCR) was used to quantify *Fusarium* concentrations. The addition of compost to peat-based growth medium increased the pH, electrical conductivity, air porosity, bulk density, and nutrition (NPK), and decreased the water holding capacity and total porosity. The use of compost did not affect the percent germination at day 15 of the tomato and pepper seedlings. The addition of compost resulted in better or comparable seedling quality compared with CK and fertilized CK. The best growth parameters were seen in tomato and pepper seedlings grown in T1 and T2, with higher morphological growth in comparison with CK and fertilized CK. However, T2 showed the highest *Fusarium* concentration compared to compost and all growth media. *Fusarium* concentrations in T1, T3, and T4 did not differ significantly from those in CK for tomato seedlings, and those in T1 and T4 were also similar to those in CK for pepper seedlings. The results suggest that biogas residues and SMS compost is a good alternative to peat, allowing 100% replacement, and that 20–50% replacement produces tomato and pepper seedlings with higher morphological growth and lower *Fusarium* concentrations.

1. Introduction

The factory growth of seedlings is an effective way to obtain high quality and stable vegetable seedlings (Ge et al., 2012). The seedlings substrate plays a very important role in factory seedling cultivation. High quality substrates could provide healthy and high-quality plants for high yield of vegetables. An eligible growth medium must provide secure growth substrate and sufficient nutrients and water, and permit oxygen absorbed by the roots and gas exchange freely through the substrates (Tam and Wang, 2015).

In many countries, peat-based growth media is the main substrate in most commercial factory seedling. However, the peat as the natural products has no renewable nature and excessive exploitation will cause environmental problems (Zhang et al., 2012). The uncontrolled mining has led to diminishing reserves and price increases, resulting in unsustainability development (Sánchezmonedero et al., 2004). High quality and low cost seedling substrate which can replace the peat need to be developed in the future. (Abad and Noguera, 2001).

Anaerobic digestion transforms organic matter into biogas which is a renewable energy source, and biogas industry is booming in China. While, sustainable process also depends on the management of biogas residues. The residues contain a lot of inorganic nutrition of N, P and K which could be absorbed by plants (Nkoa, 2014). However, the application of untreated biogas residues and their effect on soil, plant, environment and human health is still under debate. Some studies reported the high content of ammonium and chemical oxygen demand could cause high toxicity for

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animals and plants. So, pretreatment is needed to reduce the toxicity and environmental risk before the application of biogas residues.

Auricularia auricula (*A. auricula*) is a healthy mushroom that was widely cultivated in traditional Chinese cuisine and the mushroom was known as Chinese herbal medicine (Luo et al., 2009). Auricularia auricular was one of the major edible fungus in northeast China, with the production about 2.5 million tons in Heilongjiang Province. After mushroom cultivation and harvest, there is a considerable amount of residual weathered spent mushroom substrate (SMS), with 5 kg of SMS by-product produced from per 1 kg mushrooms (Semple et al., 2001). High levels of plant and animal nutrients remain in the SMS (Fidanza et al., 2010), which may result in environmental pollution if it is untreated (Rajput et al., 2009). Hence, the same as biogas residues, a suitable use of SMS is urgently needed.

Composting process is a sustainable treatment for biogas residues and SMS as stable and maturity fertilizer. While, the farmers in China are unpleasant to replace chemical fertilizers with commercial organic fertilizers, because of expensive and inefficient. So seeking for an inexpensive and sustainable way to treat biogas residues and SMS compost is urgently need. Presently, several studies have been carried out to evaluate the replacement of peat for SMS. Using a combination of peat and SMS as growth media could increase pH and electrical conductivity (Tam and Wang, 2015; Eudoxie and Alexander, 2011), as well as increased air capacity and decreased water holding capacity, when compared with peat (Medina et al., 2009). Some studies showed that SMS substrate could increases the yield and quality of various vegetables and horticultural crops (Medina et al., 2009; Polat et al., 2009). As for biogas residues, it contains high concentration of noxious and heat producing component that were harmless to plants. So, it is quite needed to promote the maturity by composting, which will be much more safe for plant. However, most of the studies focus on the application of biogas residues as soil amendment, which was not actually popularized. Hence, a novel management of replacing a part of peat by composted biogas residues and SMS can not only improve the value of organic wastes, but also promote the sustainable of soil.

Moreover, composts enhance the growth of plants as a consequence of the production of plant growth regulators and can suppress plant diseases (Yogev et al., 2011). *Fusarium* wilt caused by the soil-borne fungus *Fusarium* spp. is one of the most devastating diseases of most plants involved tomato and pepper. Compost showed a significant suppression with *Fusarium* spp. which further decrease the plant diseases in seedling and subsequent field. Real-time quantitative PCR (qPCR) provides rapid and reliable determination of the qualitative structure of the microbiome, which aids understanding of seedling quality (Martin-Sanchez et al., 2016). As yet, few studies have used qPCR to quantify *Fusarium* in seedlings.

Few studies of the use of *Auricularia auricula* spent mushroom substrate and biogas residues as a growth medium have been performed (Sendi et al., 2013; Tam and Wang, 2015). Therefore, a novel management of biogas residues and SMS compost as growth media was assessed. So, the main objectives of the present work were to evaluate the physical-chemical properties of the combination of biogas residues and SMS compost and peat, and its effect on plant growth. Innovatively, *Fusarium* spp. were accessed by qPCR to appraise the influence of compost on *Fusaium* wilt and soil.

2. Materials and methods

2.1. Composting process

A mixture of spent mushroom substrate, pig manure, and biogas residues were composted to improve their maturity. Spent black fungus mushroom substrate was obtained from Dongning town in Heilongjiang province, China. Pig manure and biogas residues were obtained from the research farm of China Agriculture University in Zhuozhou, Hebei province, China. Mixtures of spent black fungus mushroom substrate: pig manure: biogas residues at 1:1:1 ratios (v/v) were used. The C/N ratio was adjusted to 20–25 by addition of nitrogenous fertilizer (urea), and the moisture reached approximately 60–70% after complete absorption of the water in the raw materials. The composition of raw materials were shown in Table 2.

The experiment was operated in a concrete bunker (40 m × 2 m × 1.2 m) in the composting facility at the Industrial Biogas National Platform in Zhuozhou, Hebei province, China. Compost pile dimensions were as follows: 1.2 m height × 2 m width × 4 m top length × 5 m bottom length. When the compost reached the temperature of 50 °C, the compost piles were turned mechanically. When the pile was turned, the upper part was turned down, and the lower part was turned above making sure that all the compost was fully contacted with the air. The turning frequency was once per day during the thermophilic stage, and once every 5 d after the compost temperature fell below 35 °C. Composting was carried out for 120 d total.

2.2. Seedling assay

The compost and peat were mixed on a volume basis. Perlite volume was kept constant (16.67% for all treatments). The compost was mixed in different proportions with peat, to make four growth media (Table 1), with a peat: perlite mixture (5:1, v:v) as the control (CK).

The experiment had a randomized complete block design with four treatments and two replications. A tray of 72 cells were used as substrate container for plant growth, and one seed per cell. Two vegetable species, tomato and pepper, were selected and raised in the 72 cells of polystyrene trays. Plants were grown in a controlled greenhouse environment from April 2016 to May 2016. They were randomly distributed within the experiment and rotated once a week until the end of the experiment. The plants were irrigated with distilled water equally for all treatments according to their demand of water. The CK treatment included two types: one was fertilized with about 20 ppm N/P/K (drenched) every 7 d (this method is used by Dongsheng Modern Agriculture Co. Ltd., China); the other was not fertilized. No fertilization was used in the other treatments.

After 36 days of seedling, the plants reached the commercial transplanting size, 20 seedlings were selected randomly from 20 cells in per plug tray. Before measuring their dry weight (at 60 °C in a forced-air oven for 72 h), plant height, stem diameter, leaf area, leaf number, root length, silicon photon activated diode (SPAD) chlorophyll values, and fresh weight were determined. Plant height was measured from the base region of the root to the top of the plant. Stem diameter was measured at the base of the cotyledon. Leaf area was measured on the first (from top) expanded leaves using a leaf area handheld measurement instrument (American CID CI-203). The chlorophyll content was measured using a Minolta

Table 1
Types and volume ratios of the different seedling substrates.

Substrate	Treatment				
	CK	T1	T2	T3	T4
Compost	–	1	2.5	4	5
Peat	5	4	2.5	1	–
Perlite	1	1	1	1	1