

Effects of Chicken Manure Compost and High Percentage of Biochar on Container-Grown Basil (*Ocimum basilicum*)[©]

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INTRODUCTION

Biochar (BC) refers to the carbon-rich material derived from biomass (Lehmann, 2007). Research has shown that BC can be a potential alternative to commonly used substrates (Dumroese et al., 2011; Gu et al., 2013; Headlee et al., 2014; Housley et al., 2015; Vaughn et al., 2013), which is renewable and faster to generate (Yu et al., 2012) - compared to peat moss. Biochar could increase water and nutrient holding capacity, ameliorate acidity and provide a suitable environment for microbial activity (Dumroese et al., 2011; Vaughn et al., 2013; Zhang et al., 2014) and could increase plant growth under certain conditions (Headlee et al., 2014; Méndez et al., 2017; Nieto et al., 2016; Tian et al., 2012; Zhang et al., 2014). The effects of BC on container substrates depends on many factors such as its feedstock sources, production conditions, percentage of BC incorporation, other substrate components, plant type and fertility. There is no universal standard for BC incorporation for all plants. Therefore, it would be of interest to examine the characteristics of specific BC, amendment options based on its characteristics and their effects on different container-grown plants.

Composting is defined as the biological aerobic transformation of an organic byproduct into a different organic product that can be added to the soil without detrimental effects on plant growth (Baca et al., 1992). Previous research has shown that the growth indexes (GI),

shoot dry weight (DW) and total dry weight (TDW) of basil and tomato and root DW of basil grown in mixes with vermicompost [(VC) - 5, 10, 15 or 20%; by vol. and BC - 20, 40, 60 or 80%; by vol.] were similar to or higher than those in 100% commercial substrates at 9 weeks after transplanting (WAT). Chicken manure compost has relatively similar fine texture to VC, but is cheaper and more readily available than VC. Chicken manure, which was produced from chicken waste resulting from the intensive poultry industries all over the world (Li et al., 2017), is a widely used material in horticulture. Although chicken manure without being properly treated may contain some degradable nutrients and cause unpleasant environmental problems - such as odor and greenhouse gas emissions (Wu et al., 2016) - treated chicken manure can be a good compost component due to its rich nutrients, which are readily available to plants. With proper treatment, chicken manure compost (MC) may contain 8.9% nitrogen, 8.2% phosphorus and potassium, and 86.6% organic matter (Chen et al., 2017).

Based on previous positive results from using mixes of BC and VC as container substrate for basil growth - the goal of this experiment was to test the feasibility of mixes of MC (5%, by vol.), a cheaper and more readily available alternative to VC, and high percentages of BC (50, 70 or 90%, by vol.) as replacements for commercial peat-based container substrates.

MATERIALS AND METHODS

Plant material and container substrate treatments. Basil plants (*Ocimum basilicum*) seeds (Johnny's Selected Seeds, Winslow, ME) were sown in commercial propagation mix (Propagation mix; Sun Gro Inc, Agawam, MA) in 288-cell plug trays (cell depth: 2.5cm; cell top length and width: 2 cm; volume: 6 ml) on 19 March 2017, in a natural lighted glasshouse at Texas A&M University, College Station, Texas. Substrates were formulated by mixing 5% MC (by vol.; Composted Chicken manure; Back to Nature, Inc., Slaton, TX) with 50%, 70% or 90% BC (by vol.; Proton Power, Inc., Lenoir City, TN). And the remaining volumes were made up with a commercial substrate (Professional growing mix; Sun Gro Inc, Agawam, MA)

- used as the control. The BC used in this experiment was the byproduct of fast pyrolysis of mixed hardwood. The pH of the BC is 10.2 and it had 4.6 mmhos cm^{-1} soluble salts. The physical properties and particle size distribution are shown in Table 1. Uniform basil seedlings were transplanted into the experimental substrates in 6-in. azalea pots (depth: 10.8 cm; top diameter: 15.5 cm; bottom diameter: 11.3 cm) on April 4, 2017. Each pot contained one basil seedlings. Basil plants were irrigated with 200 mg L^{-1} N (20N-4.3P-16.6K) Peters Professional (Everris NA Inc, Dublin, OH) nutrient solutions.

Measurements. The EC and pH of container substrate leachates were measured weekly using handheld pH-EC meter (Hanna Instruments, Inc, Woonsocket, RI) according to the pour-through extraction method (LeBude and Bilderback, 2009). Growth index (GI) was determined by measuring plant height and two perpendicular widths at 0, 2 and 3WAT using the formula: $\text{GI} = \text{Height}/2 + (\text{Width}_1 + \text{Width}_2)/4$. Fresh weight (FW) and DW of basil harvest were measured three times at 5, 9 and 15WAT, respectively. Basil plants were harvested approximately 1 cm above the first node from the base of the plant at 5WAT to measure the first FW and DW. Basil plants were again harvested approximately 1 cm above the first node on the two lateral branches of the plants to measure the second FW and DW at 9WAT. The third FW and DW were determined by cutting the whole aboveground part of the basil plants from the substrates surface at 15WAT. Dry weight was measured after being oven-dried at 80 °C until constant weight. The total fresh weight (TFW) and TDW were determined by adding these three FWs and DWs, respectively.

Experimental design and statistical analysis. The experiment was set up in a completely randomized block design with the type of substrate being the main factor and there were five replications. Data were analyzed with one-way analysis of variance (ANOVA) using JMP Statistical Software (version Pro 12.2.0; SAS Institute, Cary, NC) and means were separated using Dunnett's test when treatments were significant at $P < 0.05$.

RESULTS AND DISCUSSION

Substrates pH and Electrical Conductivity. The pH of the substrates leachate was significantly different for all four measurements. Leachates pH of BC and MC mixes were significantly higher than the control commercial media (**Fig. 1**). As biochar percentage increased, pH of the substrate leachate increased, as reflected in a significant linear or quadratic regression correlation of pH and BC percentage (**Fig. 2**).

In the beginning of the study, EC of the BC and MC mixes leachates were similar to that of the control commercial media (**Fig. 3**). However, EC of the BC and MC mixes leachates were higher than the control at 1WAT, similar to the control at 2WAT and lower at 3WAT, respectively. This result was not consistent with the results of Ruqin et al. (2015) who described that EC increased with increased BC rate. Tian et al. (2012) also found that adding 50% (by vol.) biochar made from green waste to peat moss media significantly increased EC. The different properties of the BC used in this research may have caused the difference in EC levels.

Plant Growth and Development. Growth indexes of the basil plants grown in substrates with 5% MC mixed with 50%, 70% or 90% BC were all similar to those grown in the control commercial media at 2 and 3 WAT (**Fig. 4**). There were no significant differences between the TFW and TDW of three basil cuttings grown in BC and MC mixes and the control (**Fig. 5**). Yu et al. (2012) reported that when substituting Sunshine #1 Mix with 60 or 80% pinewood BC (by vol.), the DW of basil plants grown in mixes with BC was similar to or higher than the control.

From this preliminary experiment, chicken manure compost (5%, by vol.) may be a good potential amendment candidate for incorporating high volume biochar (50, 70 or 90%, by vol.) in commercial substrates to grow basil (*Ocimum basilicum*). More species need to be tested for future use.

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Table 1. Physical Properties and particle size distribution of the mixed hardwood biochar.

Total Porosity	Container Capacity (% vol)	Air Space	Bulk Density (g cm ⁻³)	Particle Size Distribution		
				Large (<6.3mm, >2mm)	Medium (<2mm, >0.5mm)	Fine (<=0.5mm)
84.7	60.3	24.4	0.15	2.6%	32.9%	64.5%

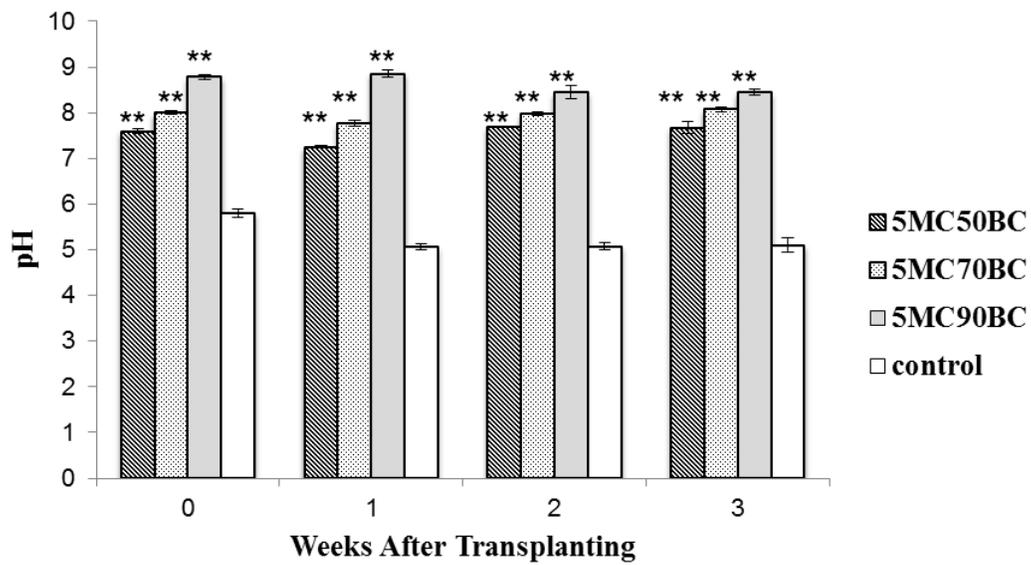


Figure 1. Substrate pH (mean \pm standard error) in leachates of containers with 5% (by vol.) chicken manure compost (MC) - mixed with 50%, 70% or 90% (by vol.) biochar (BC). The control was a peat-based, commercial media. The asterisks indicated significant difference from the control using Dunnett's tests [$P < 0.01$ (**)].

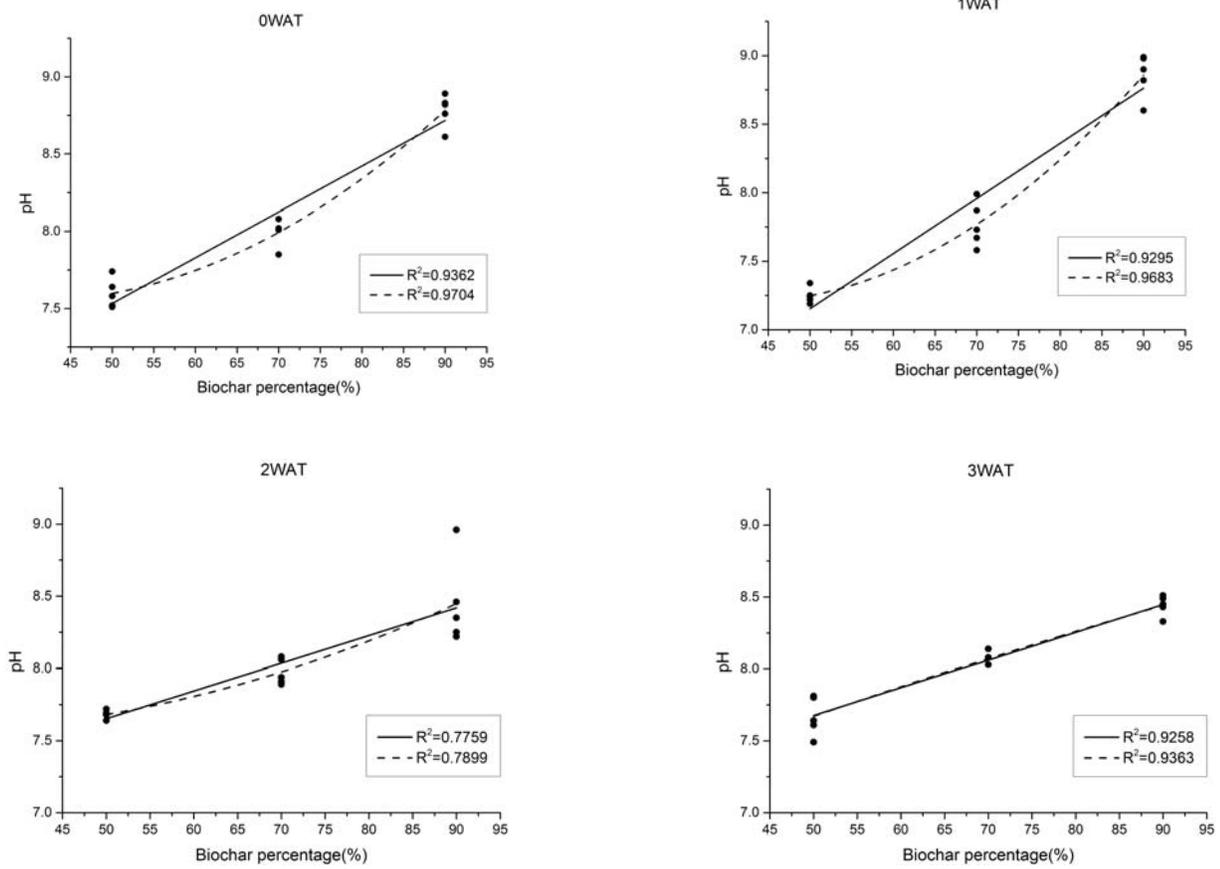


Figure 2. Linear (solid line) and quadratic (dashed line) regression correlation of the biochar percentages and the substrate pH in leachates of containers with 5% (by vol.) chicken manure compost (MC) mixed with 50%, 70% or 90% (by vol.) biochar at 0, 1, 2 and 3 weeks after transplanting (WAT).

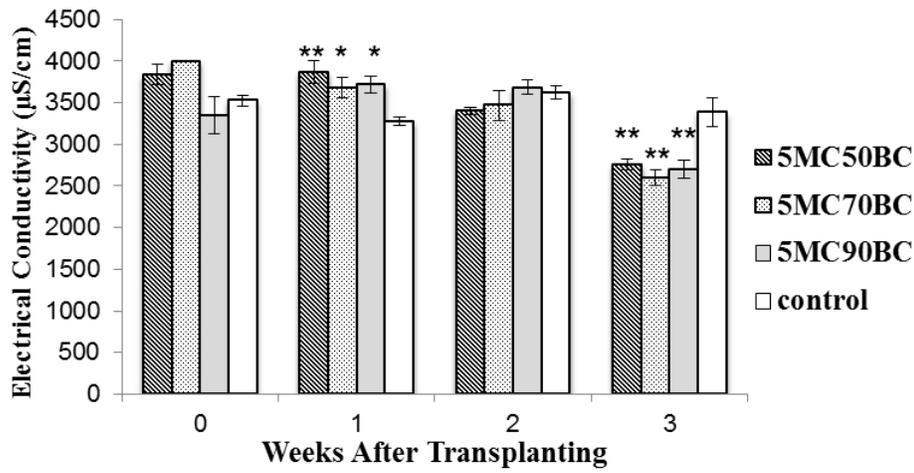


Figure 3. Substrate electrical conductivity (EC) (mean \pm standard error) in leachates of containers with 5% (by vol.) chicken manure compost (MC) mixed with 50%, 70% or 90% (by vol.) biochar (BC) and a control composed of a commercial peat-based media. The asterisks indicated significant difference from the control using Dunnett's tests [$P < 0.05$ (*) or $P < 0.01$ (**)].

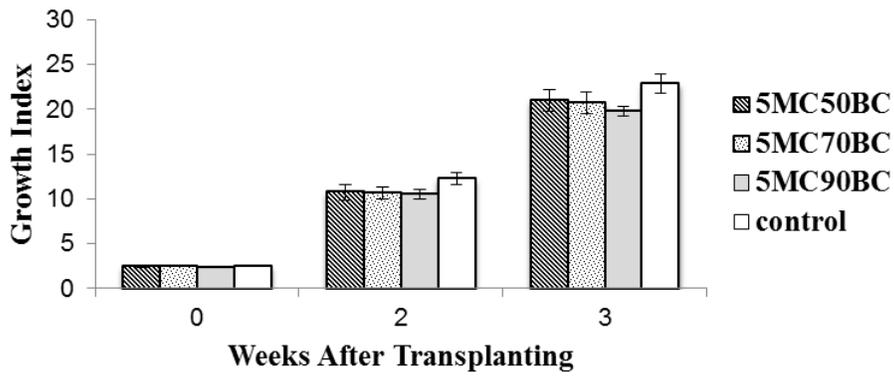


Figure 4. Growth index of basil (*Ocimum basilicum*) (mean \pm standard error) at 0, 2, 3 weeks after transplanting when grown in mixes with 5% (by vol.) chicken manure compost (MC) and 50%, 70% or 90% (by vol.) biochar (BC) and a control composed of a commercial peat-based media.

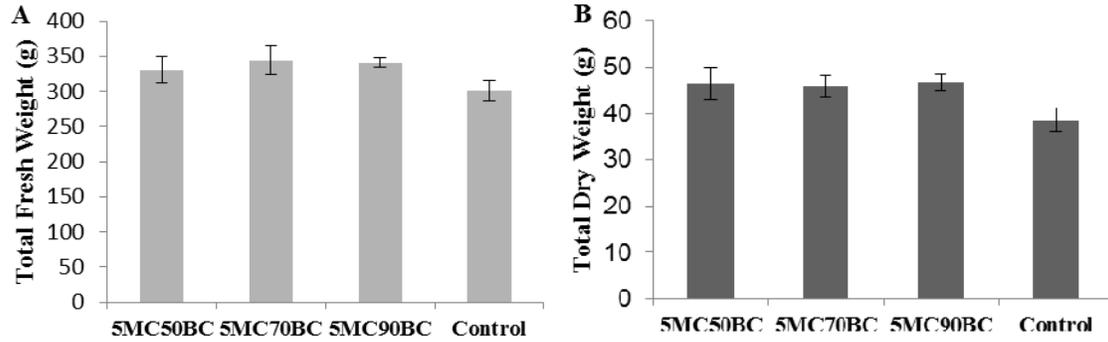


Figure 5. Total fresh weight (A) and total dry weight (B) of basil (*Ocimum basilicum*) (mean \pm standard error) grown in mixes with 5% (by vol.) chicken manure compost (MC) and 50%, 70% or 90% (by vol.) biochar (BC) and a control composed of a commercial peat-based media.