Effects of chicken manure compost and high percentage of biochar on container-grown basil (*Ocimum basilicum*)©

L. Huang[1,a], P. Yu[1] and M. Gu[2,b]

[1]Department of Horticultural Sciences, Texas A&M University, College Station, Texas 77843, USA; [2]Department of Horticultural Sciences, Texas A&M AgriLife Extension Service, College Station, TX 77843, USA.

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 depend 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 (MC) 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 wildly 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, 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, Maine) were sown in commercial propagation mix (propagation mix; Sun Gro Inc, Agawam,

[a]E-mail: huanglan92@tamu.edu
[b]E-mail: mgu@tamu.edu

Massachusetts) in 288-cell plug trays (cell depth: 2.5 cm; cell top length and width: 2 cm; volume: 6 mL) on March 19, 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, Texas) with 50, 70 or 90% BC (by vol.; Proton Power, Inc., Lenoir City, Tennessee). And the remaining volumes were made up with a commercial substrate (Professional growing mix; Sun Gro Inc, Agawam, Massachusetts)—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 seedling. Basil plants were irrigated with 200 mg L^{-1} N (20N-4.3P-16.6K) Peters Professional (Everris NA Inc, Dublin, Ohio) nutrient solutions.

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

Total porosity	Container capacity	Air space	Bulk density	Particle size distribution		
				Large	Medium	Fine
	(% vol)		($g\ cm^{-3}$)	(<6.3 mm, >2 mm)	(<2 mm, >0.5 mm)	(<=0.5 mm)
84.7	60.3	24.4	0.15	2.6%	32.9%	64.5%

Measurements

The electrical conductivity (EC) and pH of container substrate leachates were measured weekly using handheld pH-EC meter (Hanna Instruments, Inc., Woonsocket, Rhode Island) according to the pour-through extraction method (LeBude and Bilderback, 2009). Growth index was determined by measuring plant height and two perpendicular widths at 0, 2 and 3 WAT using the formula: GI=Height/2+(Width1+Width2)/4. Fresh weight (FW) and DW of basil harvest were measured three times at 5, 9 and 15 WAT, respectively. Basil plants were harvested approximately 1 cm above the first node from the base of the plant at 5 WAT 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 9 WAT. The third FW and DW were determined by cutting the whole aboveground part of the basil plants from the substrates surface at 15 WAT. 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, North Carolina) 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 (Figure 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 (Figure 2).

In the beginning of the study, EC of the BC and MC mixes leachates were similar to that of the control commercial media (Figure 3). However, EC of the BC and MC mixes leachates were higher than the control at 1 WAT, similar to the control at 2 WAT and lower at 3 WAT, respectively. This result was not consistent with the results of Fan 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.

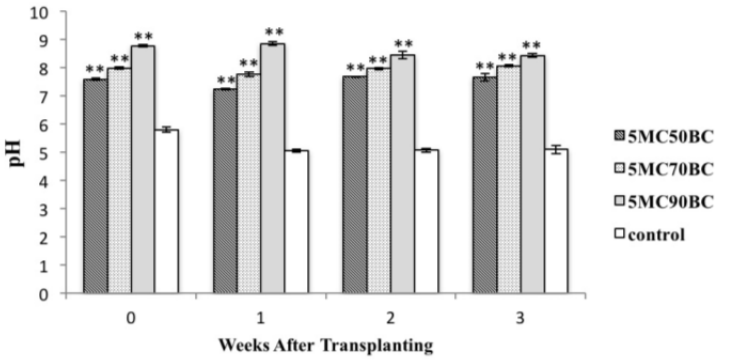

Figure 1. Substrate pH (mean ± standard error) in leachates of containers with 5% (by vol.) chicken manure compost (MC)—mixed with 50, 70 or 90% (by vol.) biochar (BC). The control was a peat-based, commercial media. The asterisks indicated significant difference from the control using Dunnett's tests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

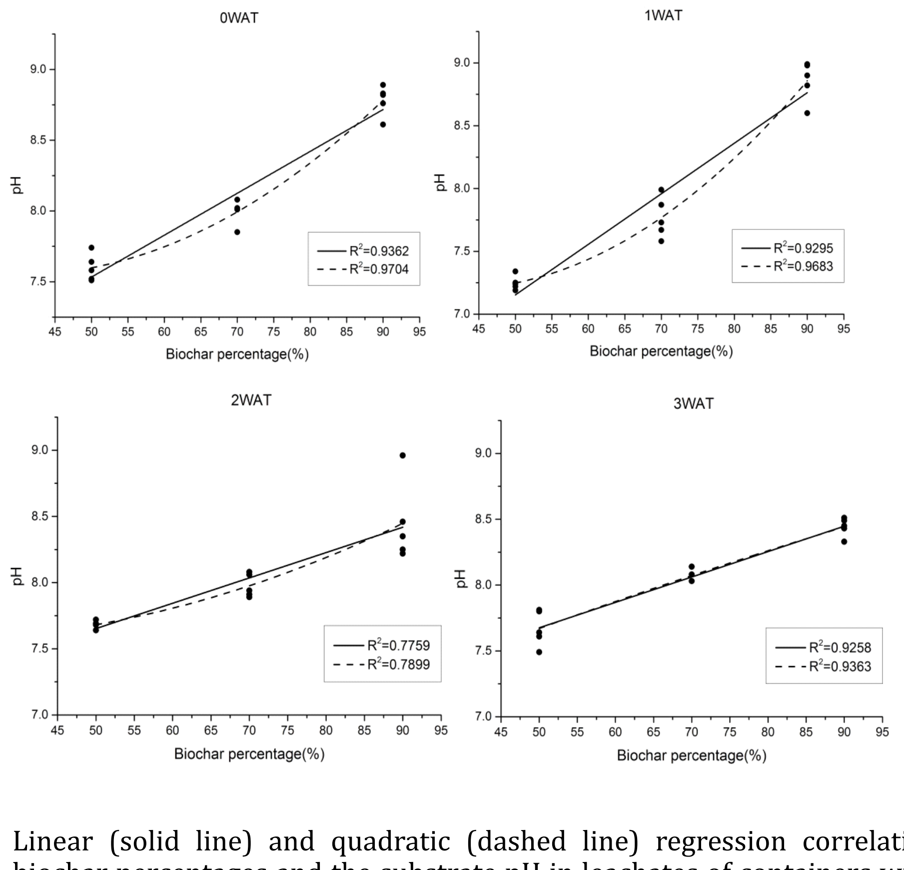

Figure 2. Linear (solid line) and quadratic (dashed line) regression correlation of the biochar percentages and the substrate pH in leachates of containers with 5% (by vol.) chicken manure compost (MC) mixed with 50, 70 or 90% (by vol.) biochar at 0, 1, 2 and 3 weeks after transplanting (WAT).

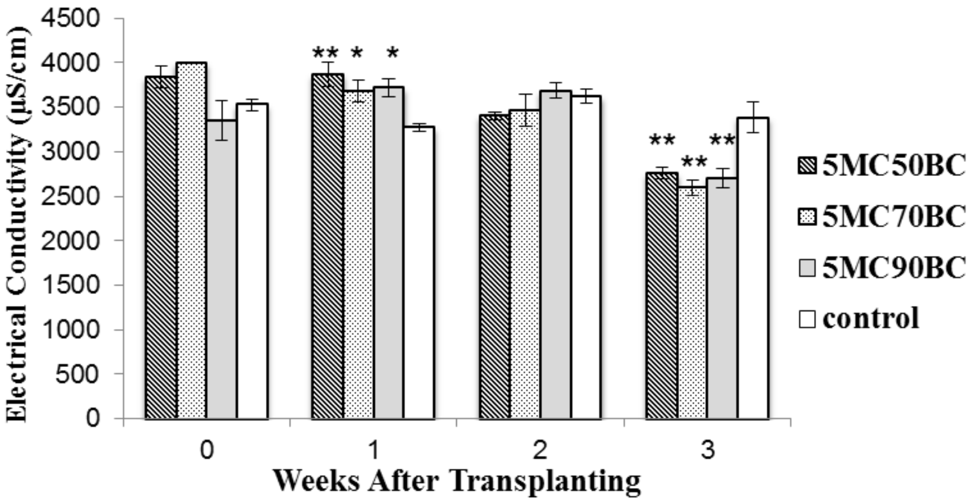

Figure 3. Substrate electrical conductivity (EC) (mean ± standard error) in leachates of containers with 5% (by vol.) chicken manure compost (MC) mixed with 50, 70 or 90% (by vol.) biochar (BC) and a control composed of a commercial peat-based media. The asterisks indicated significant difference from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

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 (Figure 4). There were no significant differences between the TFW and TDW of three basil cuttings grown in BC and MC mixes and the control (Figure 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.

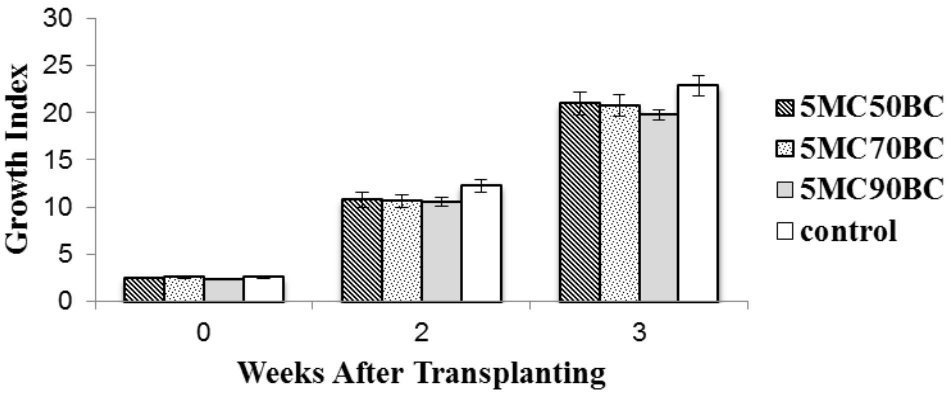

Figure 4. Growth index of basil (*Ocimum basilicum*) (mean ± standard error) at 0, 2, 3 weeks after transplanting when grown in mixes with 5% (by vol.) chicken manure compost (MC) and 50, 70 or 90% (by vol.) biochar (BC) and a control composed of a commercial peat-based media.

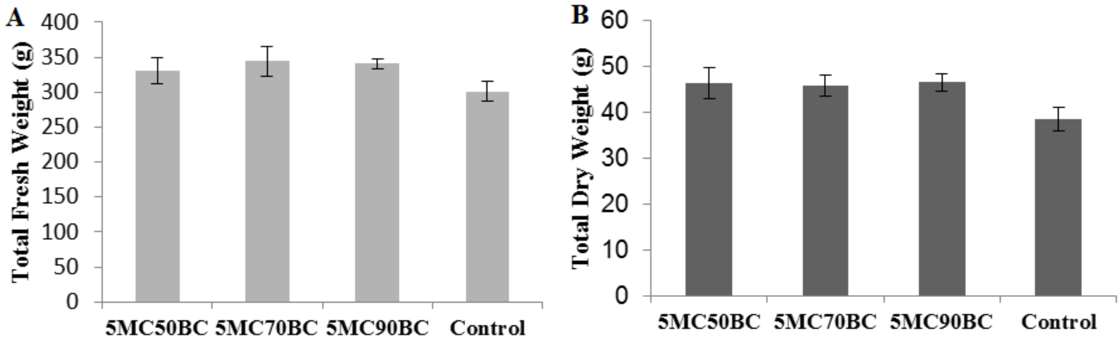

Figure 5. Total fresh weight (A) and total dry weight (B) of basil (*Ocimum basilicum*) (mean± standard error) grown in mixes with 5% (by vol.) chicken manure compost (MC) and 50, 70 or 90% (by vol.) biochar (BC) and a control composed of a commercial peat-based media.

Literature cited

Baca, M.T., Fornasier, F., and de Nobili, M. (1992). Mineralization and humification pathways in two composting processes applied to cotton wastes. J. Ferment. Bioeng. *74* (*3*), 179–184 https://doi.org/10.1016/0922-338X(92)90080-E.

Chen, J., Shi, L., Liu, H., Yang, J., Guo, R., Chen, D., Jiang, X., and Liu, Y. (2017). Screening of fermentation starters for organic fertilizer composted from chicken manure. Asian Agric. Res. *9* (*4*), 92–98.

Dumroese, R.K., Heiskanen, J., Englund, K., and Tervahauta, A. (2011). Pelleted biochar: chemical and physical properties show potential use as a substrate in container nurseries. Biomass Bioenergy *35* (*5*), 2018–2027 https://doi.org/10.1016/j.biombioe.2011.01.053.

Fan, R., Luo, J., Yan, S., Zhou, Y., and Zhang, Z. (2015). Effects of biochar and super absorbent polymer on substrate properties and water spinach growth. Pedosphere *25* (*5*), 737–748 https://doi.org/10.1016/S1002-0160(15)30055-2.

Gu, M., Li, Q., Steele, P.H., Niu, G., and Yu, F. (2013). Growth of 'Fireworks' gomphrena grown in substrates amended with biochar. J. Food. Agric. Environ. *11*, 819–821.

Headlee, W.L., Brewer, C.E., and Hall, R.B. (2014). Biochar as a substitute for vermiculite in potting mix for hybrid poplar. BioEnergy Research *7* (*1*), 120–131 https://doi.org/10.1007/s12155-013-9355-y.

Housley, C., Kachenko, A., and Singh, B. (2015). Effects of *Eucalyptus saligna* biochar-amended media on the growth of *Acmena smithii, Viola* var. hybrida, and *Viola* × *wittrockiana.* J. Hortic. Sci. Biotechnol. *90* (*2*), 187–194 https://doi.org/10.1080/14620316.2015.11513171.

LeBude, A., and Bilderback, T. (2009). The Pour-Through Extraction Procedure: a Nutrient Management Tool for Nursery Crops. North Carolina Cooperative Extension. AG-717-W.

Lehmann, J. (2007). A handful of carbon. Nature *447* (*7141*), 143–144 https://doi.org/10.1038/447143a. PubMed

Li, C., Strömberg, S., Liu, G., Nges, I.A., and Liu, J. (2017). Assessment of regional biomass as co-substrate in the anaerobic digestion of chicken manure: impact of co-digestion with chicken processing waste, seagrass and *Miscanthus.* Biochem. Eng. J. *118*, 1–10 https://doi.org/10.1016/j.bej.2016.11.008.

Méndez, A., Cárdenas-Aguiar, E., Paz-Ferreiro, J., Plaza, C., and Gascó, G. (2017). The effect of sewage sludge biochar on peat-based growing media. Biol. Agric. Hortic. *33* (*1*), 40–51 https://doi.org/10.1080/01448765.2016.1185645.

Nieto, A., Gascó, G., Paz-Ferreiro, J., Fernández, J., Plaza, C., and Méndez, A. (2016). The effect of pruning waste and biochar addition on brown peat based growing media properties. Sci. Hortic. (Amsterdam) *199*, 142–148 https://doi.org/10.1016/j.scienta.2015.12.012.

Tian, Y., Sun, X., Li, S., Wang, H., Wang, L., Cao, J., and Zhang, L. (2012). Biochar made from green waste as peat substitute in growth media for *Calathea rotundifo*la cv. Fasciata. Scient. Hort. *143*, 15–18 https://doi.org/10.1016/j.scienta.2012.05.018.

Vaughn, S.F., Kenar, J.A., Thompson, A.R., and Peterson, S.C. (2013). Comparison of biochars derived from wood pellets and pelletized wheat straw as replacements for peat in potting substrates. Ind. Crops Prod. *51*, 437–443 https://doi.org/10.1016/j.indcrop.2013.10.010.

Wu, S., Ni, P., Li, J., Sun, H., Wang, Y., Luo, H., Dach, J., and Dong, R. (2016). Integrated approach to sustain biogas production in anaerobic digestion of chicken manure under recycled utilization of liquid digestate: dynamics of ammonium accumulation and mitigation control. Bioresour. Technol. *205*, 75–81 https://doi.org/10.1016/j.biortech.2016.01.021. PubMed

Yu, F., Steele, P.H., Gu, M., and Zhao, Y. (2012). Using biochar as container substrate for plant growth. Google Patents.

Zhang, L., Sun, X.-y., Tian, Y., and Gong, X. (2014). Biochar and humic acid amendments improve the quality of composted green waste as a growth medium for the ornamental plant *Calathea insignis.* Sci. Hortic. (Amsterdam) *176*, 70–78 https://doi.org/10.1016/j.scienta.2014.06.021.