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Hardwood and Sugarcane Biochar Can Replace Bark-Based Substrate for Container Production of Tomato (*Solanum lycopersicum*) and Basil (*Ocimum basilicum*) Plants

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Abstract

Biochar (BC) has potential as a supplement for more expensive peat and bark media components in container production of plants. This research demonstrates that mixed hardwood biochar (HB) can replace 50% of bark-based substrate, while sugarcane biochar (SBB) can replace 70% of bark-based substrate in container mixes for tomato and basil production. There was no adverse effect on plant growth. Tomato plants grown in SBB amended substrates had lower total dry weight, but similar or higher fruit dry weight in comparison to the control. The suitable rates of SBB and HB to replace bark-based substrate for container production of other crops are worthy of further investigation.

INTRODUCTION

Biochar (BC) is rich-carbon material with porous structure produced by the thermochemical decomposition of biomass in an oxygen depleted or oxygen-limited atmosphere (Demirbas and Arin, 2002; Lehmann, 2007; Nartey and Zhao, 2014). Research has shown that BC from certain raw materials and conditions can be a potential alternative to commonly used substrates (Gu et al., 2013; Guo et al., 2018a; Guo et al., 2018b;

Huang and Gu, 2019; Huang et al., 2019) due to its suitable properties for plants growth. BC can increase water and nutrient holding capacity, ameliorate acidity and provide a suitable environment for plants (Dumroese et al., 2011; Vaughn et al., 2013; Zhang et al., 2014). Under certain conditions, BC can increase greenhouse crop growth, yield and quality (Tian et al., 2012; Headlee et al., 2014; Zhang et al., 2014; Nieto et al., 2016; Méndez et al., 2017).

There are huge substrate demands for greenhouse plants production (Gu et al., 2013). According to the USDA, around 5.4 million (M) ft^3 substrate was used for potted plants production in 2017. The substrate use is considerably greater, since only entities with over $1 million in sales from 15 states were included in the survey (USDA-NASS, 2018). The substrate commonly used for potted plants production in greenhouse is mainly peat moss-based. However, there are negative environmental impacts with peat moss extraction, such as destroying rare habitats and cultural heritage, and adversely affecting water management and climate change (Alexander et al., 2008). Thus, the United Kingdom and other countries have environmental policies to restrain unnecessary peat extraction and to encourage use of peat alternatives. The price of peat and bark is constantly increasing, especially when transportation cost were taken into consideration (USGS, 2016). This directly affects growers profitability (Gu et al., 2013). Bark is a peat alternative. While it is less expensive than peat moss, the supply of bark has decreased due to fluctuation in housing demand, lumber and paper supplies (Wright and Browder, 2005).

Research has focused on finding commonly used container substrate alternatives from industrial and agricultural waste - such as switchgrass and miscanthus straw (Altland and Krause, 2009; Altland and Locke, 2011), clean chip residuals (Boyer et al., 2008) and animal manures. Although some of these materials have potential to be good substrate components, the lack of reliable supplies limited their use. As a novel material, which has potential to be widely used as substrate component, BC has also attracted researchers' attention. There is no universal standard for BC addition to plant production. The effects of BC on container substrates depend on many factors including BC feedstock, production conditions and the percentage of BC. Our previous study showed that mixed hardwood biochar (HB) performed well as greenhouse media amendments (Huang et al., 2019). This research was conducted to determine the effects of different BC as bark-based substrate amendments on container plants growth.

MATERIALS AND METHODS

Plant material and experimental design

Tomato (*Solanum lycopersicum* 'Red Robin™') (Fred C. Gloeckner, Harrison, NY, USA) and basil (*Ocimum basilicum*) (Johnny's Selected Seeds, Winslow, ME, USA) seeds were sown in plug trays (cell depth: 5-cm; cell top length and width: 4-cm; volume: 55ml) with commercial mix (BM2 Berger, Saint-Modeste, Quebec, Canada), one seed per cell on 26 February 2019. After the first pair of true leaves expanded, uniform seedlings were transplanted into 6-in. azalea pots (depth: 10.8-cm; top diameter: 15.5-cm; bottom diameter: 11.3-cm; volume: 1,330 ml) with commercial potting mix (Jolly Gardener, Oldcastle Lawn & Garden Inc. Atlanta, GA) incorporated with either sugarcane biochar (SBB) at two rates (50%, 70%, by vol.) or mixed hardwood biochar (HB) at 50%. A commercial potting mix was used as control. The SBB was produced by American Biocarbon LLC (White Castle, LA) using proprietary methods, and the HB was the by-product of fast pyrolysis of mixed hardwood produced by Proton Power Inc. (Lenoir City, TN, USA). During transplanting, slow-release fertilizer Osmocote Plus (15-9-12, Scotts-Sierra Horticultural Products Company, Marysville, Ohio) were applied as surface dressing at the rate of 4.8 g/pot for basil and 7.7g/pot for tomato. This experiment was designed as random complete block design with six replications per treatment. Pots were placed in a greenhouse at Texas A&M University, College Station, TX. The average greenhouse temperature, relative humidity and dew point were 23.7℃, 81.8% and 19.6℃, respectively.

Measurements

Potting mix physio-chemical properties

Physical properties of all the potting mixes were measured using North Carolina State University Horticultural Substrates Laboratory Porometer (Fonteno et al., 1995). The leachate electrical conductivity (EC) and pH were measured biweekly starting at one week after transplanting (1WAT) with a portable EC/pH meter by pour-through method (LeBude and Bilderback, 2009).

Plant growth

Plant growth index was calculated at 1, 3, 5 and 7WAT using the formula-- Plant growth index=Plant height/2+(Plant width 1+Plant width 2)/4. Plant stem, leaf, fruit (tomato) and flower (basil) were harvested separately and their dry weight (SDW, LDW, FDW) were weighed after being oven-dried to a constant weight at 80 °C. Total dry weight (TDW) of above-ground part were calculated by adding SDW, LDW, and/or FDW. Plant roots were washed under running water after harvest, and root length, root surface area, root diameter and the number of root tips were measured by scanning under a root scanner (WinRHIZO, Regent Instruments Canada Inc., Canada).

RESULTS

Potting mix physio-chemical properties

The HB is alkaline while SBB is acidic. Most of the mixes' physical properties were within the recommended range even though for SBB mix (Table 1). Their TP and CC were slightly higher than the recommended ones and 50% SBB mix had slightly lower than recommended. For both tomato and basil (Fig.1), the EC of all treatments decreased during the experiment.

Table 1. The physio-chemical properties of biochar, commercial substrate and their mixes.

Composition	pH	EC µS/cm	TP[w] %	CC %	AS %	BD g/cm^3
SBB[X]	5.9	753	74	71	3	0.11
HB[Y]	10.1	1,058	87	66	20	0.13
50%SBB+50%CS	6.3	2,073	81	75	7	0.13
50%HB+50%CS	7.5	1,370	78	62	17	0.13
70%SBB+30%CS	6.4	1,830	89	76	13	0.14
Commercial Substrate[Z]	6.5	1,819	97	85	12	0.15
Suitable range [R]	-	-	50-80	45-65	10-30	0.19-0.7

[X] SBB =Sugarcane Bagasse Biochar produced by American Biocarbon LLC.
[Y]HB = Mixed Hardwood Biochar provided by Texas A&M and produced by Proton Power, Inc.
[Z] Commercial bark-based substrate, Jolly Gardener, Oldcastle Lawn & Garden Inc. Atlanta, GA, USA. [w] TP=Total porosity, CC=container capacity, AS=Air space, BD= Bulk density. [R] Recommended physical properties of container substrate by (Yeager et al., 1997).

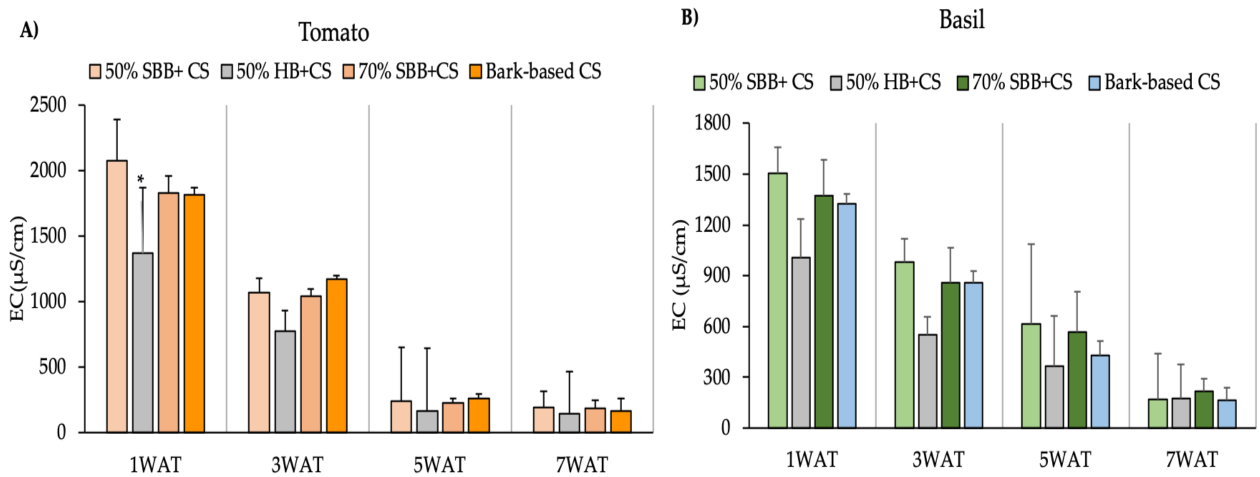

Figure 1. EC (mean ± standard error) of containers media with 50% SBB, 50%HB, 70%SBB or 0% BC (by vol.) mixed with bark-based commercial substrate in the growing period, grown with tomato A) and basil B) plants. * indicated significant difference from the control using Dunnett's test at P<=0.05.

For tomato, (Fig. 2A), treatments with 50%HB had significantly higher pH than the control at 1, 3 and 7WAT. At 1WAT, 50% SBB treatment had significantly lower pH than the control, while at 7WAT, 70%SBB had significantly lower pH than the control. For basil plants (Fig. 2B), treatment with 50%HB had significantly higher pH in comparison to the control for all the weeks, and SBB treatments (both 50% and 70%) had significantly lower pH compared to the control at 5WAT and 7WAT.

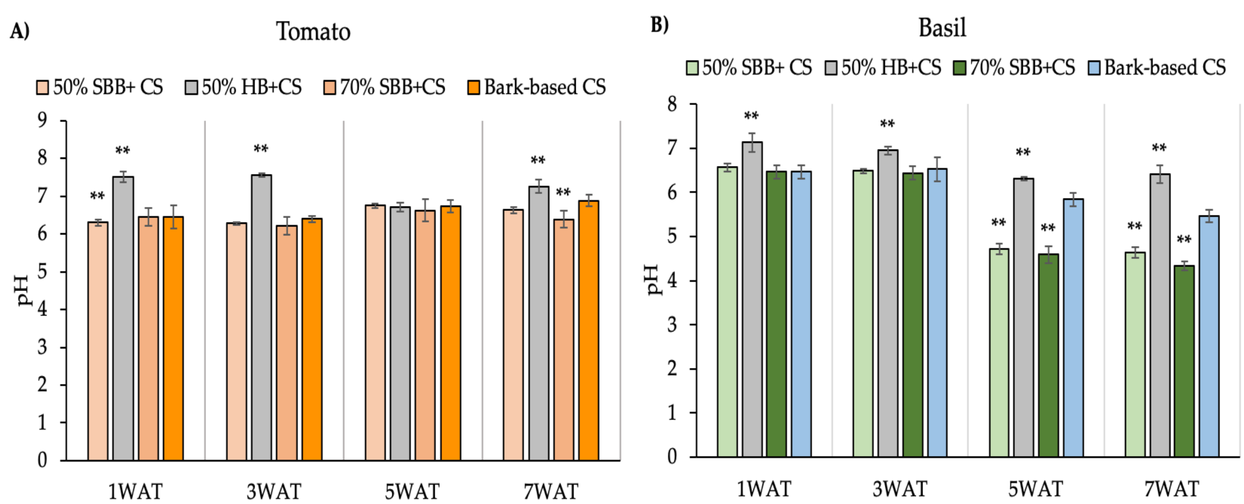

Figure 2. The pH (mean ± standard error) of containers media with 50% SBB, 50%HB, 70%SBB or 0% BC (by vol.) mixed with bark-based commercial substrate in the growing period, grown with tomato A) and basil B) plants. * indicated significant difference from the control using Dunnett's test at P<=0.05(*), P<=0.01(**).

Plant growth

For tomato plants (Fig. 3A), the 70%SBB had significantly higher GI than the control at 5WAT. There we no other significant differences among the four treatments.

For basil plants (Fig. 3B), there were no significant differences among the four treatments.

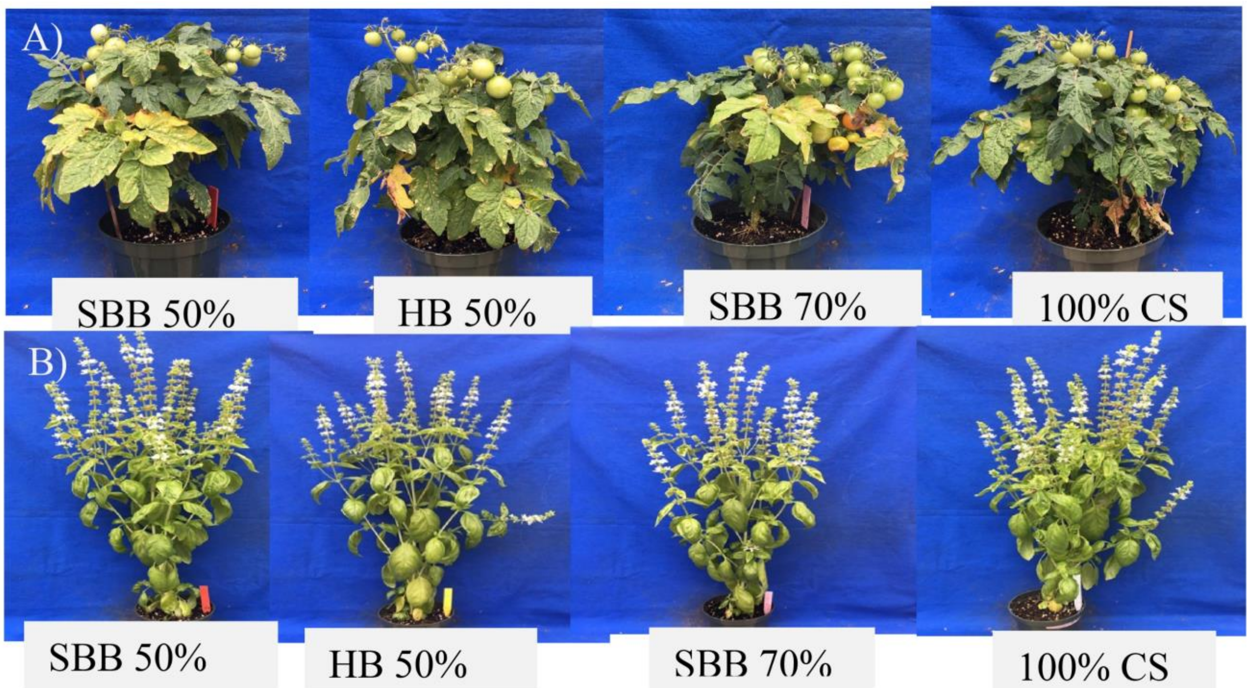

Figure 3. Tomato A) and basil B) plants after grown in containers with 50% SBB, 50%HB, 70%SBB or 0% BC (by vol.) mixed with bark-based commercial substrate for 7 weeks.

For tomato plants, there were no significant differences among the four treatments on root length and average diameter (Fig. 4A). The SBB treatments had a significantly smaller root surface area than the control. Treatments with 50% SBB had significantly less root tips compared to the control while other treatments had similar or more tips than the control.

For basil plants (Fig. 4B), there were no significant differences among the treatments in root surface area. All the BC treatments had significantly shorter root length than the control, but a significantly larger average diameter. Treatments with 50% of BC had significantly less root tips compared to the control.

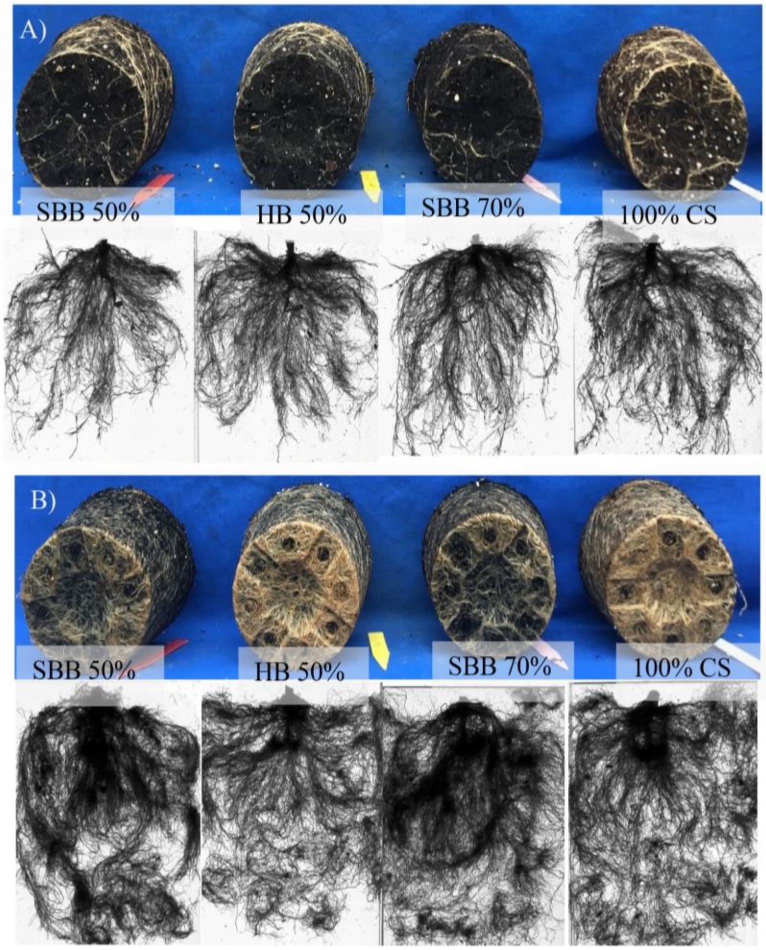

Figure 4. Root development of tomato A) and basil B) plants after grown in containers with 50% SBB, 50%HB, 70%SBB or 0% BC (by vol.) mixed with bark-based commercial substrate for 7 weeks.

CONCLUSION

Mixed Hardwood biochar can replace 50% of bark-based substrate and sugarcane biochar can replace 70% of bark-based substrate in the potting mixes for tomato and basil production, without affecting the plant growth in this experiment. Tomato plants grown in SBB amended substrates had lower TDW, but had similar or higher FDW compared to the commercial control. The suitable rates of SBB and HB to replace bark-based substrate for container production of other crops merits further investigation.

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