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The Effects of Biochar Incorporation on Plant Growth in Container Production

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Abstract

Biochar is the solid product of pyrolysis of various biomasses, including a lot of agricultural and forestry waste products. The physical and chemical properties of biochars vary significantly due to the differences in feedstock, pre- and post-treatment, and pyrolysis conditions. Based on our ten years of research on incorporating different types of biochar in container substrate, we are confident that biochar made of locally available materials, such as mixed hardwood or sugarcane bagasse, could replace significant amount (50%) of peat or bark in container mix, without negatively affecting plant growth - and in many cases could be beneficial.

INTRODUCTION

In the absence of oxygen or with limited oxygen, biomass heated at high temperature under high pressure will yield biogas, bio-oil and biochar. Depending on many factors, such as source of feedstock, temperatures and pressure, and pre-and post-treatment, biochar could have different properties, pH, electric conductivity (EC), bulk density, particle size distribution, and surface area. The biochar's physical properties as container substrate such as air space, container capacity and total porosity, will be different too.

For example, biochar from fast pyrolysis of pine wood (PB) at 450 °C has an EC of 0.15 mS·cm^{-1} and pH of 5.3 (Table 1). The pH and EC of Sugarcan bagasse biochar (SBB; American Biocarbon LLC White Castle, LA, USA) are 5.9and 0.75 mS·cm^{-1}, respectively, and the pH and EC of mixed hardwood biochar (HB; Proton Power Inc. Lenouir City, TN, USA) were 10.1and 1.06 mS·cm^{-1}, respectively. Similarly, the total porosity (TP), container capacity (CC), air space (AS), and bulk density (BD) of these biochars are also different.

The chemical and physical properties of substrate components are not as important as the properties of the container substrate as a whole. Based on the chemical and physical properties of different types of biochars, appropriate substrate components could be mixed at certain ratios to make the final mix with chemical and physical properties within or close to the suitable ranges (Table 1).

Table 1. The pH, EC, total porosity (TP), container capacity (CC), air space (AS), and bulk density (BD) of pine wood biochar (PBC), sugarcane bagasse biochar (SBB), mixed hardwood biochar (HB), perlite (P), peatmoss (PM), P:PM mix (70:30, by vol.) and a commercial substrate (CS), and suitable ranges.

Substrate Component [z]	pH	EC (mS/cm)	TP (%)	CC (%)	AS (%)	BD (g/cm^3)
PBC	5.3	0.15	83	49	34	0.17
SBB	5.9	0.75	74	71	3	0.11
HB	10.1	1.06	87	66	20	0.13
P	7.3	0.57	92	59	34	0.05
PM	5.03	0.18	69	58	11	0.11
PM:P=70:30	5.6	0.16	79	62	16	0.09
CS	6.5	1.82	97	85	12	0.15
Suitable range	6.2-6.8	--	50-80	45-65	10-30	0.19-0.7

[z] SBB=Sugarcane bagasse biochar produced by American Biocarbon LLC, LA, USA; HB=Mixed Hardwood biochar produced by Proton Power, Inc, TN, USA; CS=commercial substrate, Jolly Gardener, Oldcastle Lawn & Garden Inc., Atlanta, USA; P=Perlite (Kinney Bonded Warehouse, Tyler, TX, USA; PM=Peat moss, Voluntary purchasing Group Inc., Bonham, TX, USA.

PINE WOOD BIOCHAR (PBC)

Preliminary experiments found the growth of 'Fireworks' gomphrena was improved when grown in peat-based commercial substrate (CS) mixed with 10%, 20% and 30% (by volume; Gu et al., 2013) PBC. Then PBC was used in container substrate to replace pine bark (PB) or CS at 20%, 40%, 60%, 80% or 100% (by volume). Tomato, lettuce (Fig. 1), chrysanthemum and basil (Fig. 2) were grown in these mixes and had similar growth in mixes with up to 60% or 80% PBC compared to PB and CS, respectively (Choi et al., 2018; Peng et al., 2018).

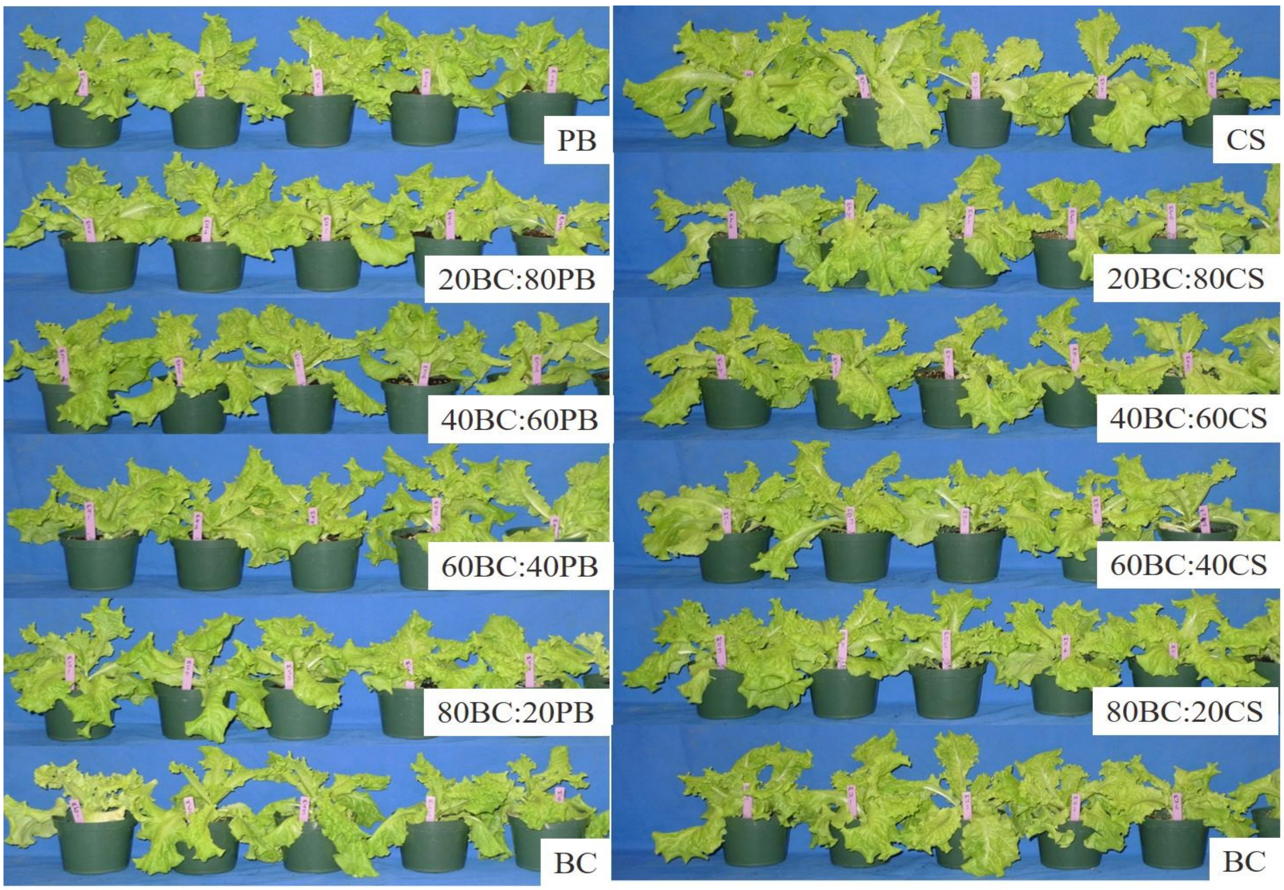

Figure 1. 'Simpson' lettuce grown in pine bark (PB), pine wood biochar (BC):PB mixes (numbers indicate the percentage by volume), peat-based commercial substrate (CS), BC:CS mixes, and BC.

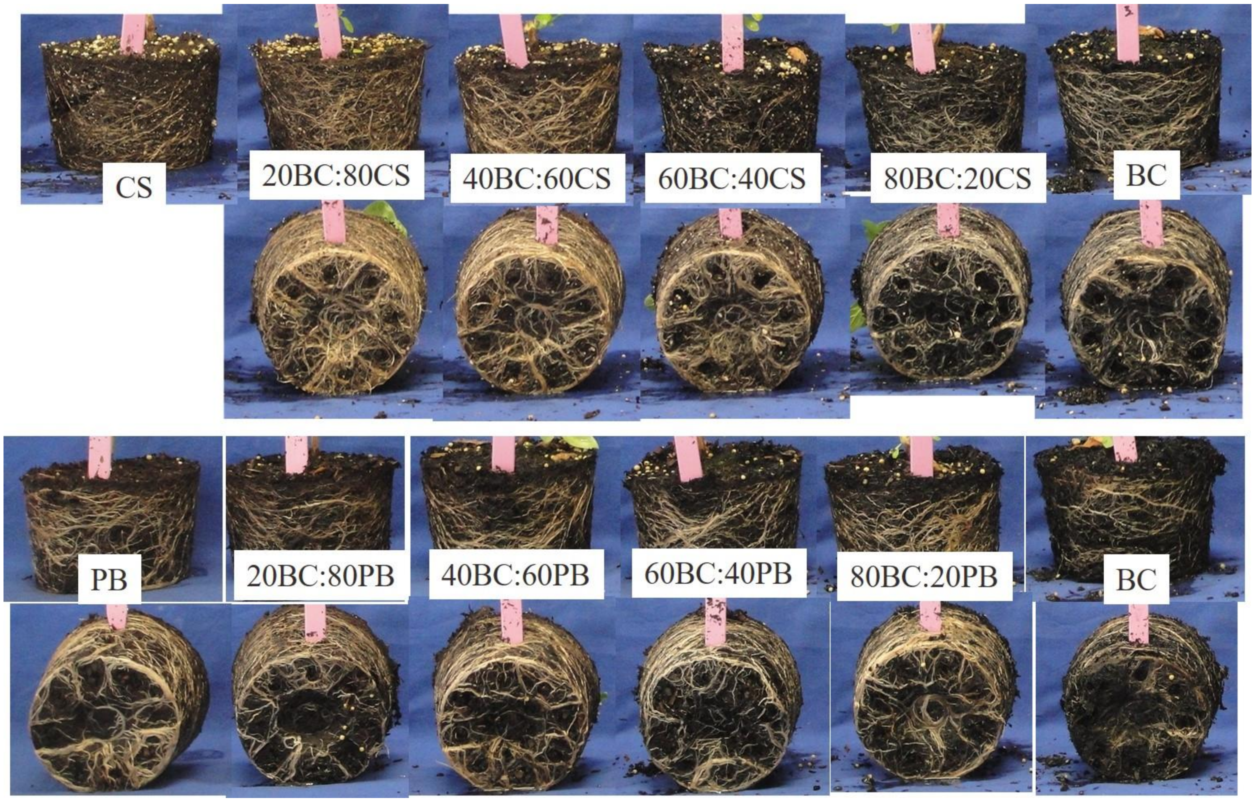

Figure 2. The root balls of 'Genovese' basil grown in pine bark (PB), pine wood biochar (BC):PB mixes (numbers indicate the percentage by volume), peat-based commercial substrate (CS), BC:CS mixes, and BC.

Two relatively long-growth (3-4 months) greenhouse crops, poinsettia (Fig 3) and Easter lily (Fig. 4), were tested in CS replaced by PBC. Poinsettia plants grown in up to 60% PBC were similar to plants in CS and Easter lily up to 80%. The plants had similar visual rating, respectively.

Figure 3. 'Prestige Red' poinsettia grown in peat-based commercial substrate (CS), pine wood biochar (BC):CS mixes (numbers indicate the percentage by volume), and BC.

With the type of plants and duration of production tested, the PBC could be potentially used at high incorporation (up to 80%) in growing greenhouse crops. During these experiments, plants were maintained as the plants grown in CS. If production practices, such as fertilization and watering schedule, were adjusted to meet the plants needs in mixes with high rates of PBC, plants in PBC mixes may have grown even better. And it may be possible to use 80%-100% PBC as container substrate.

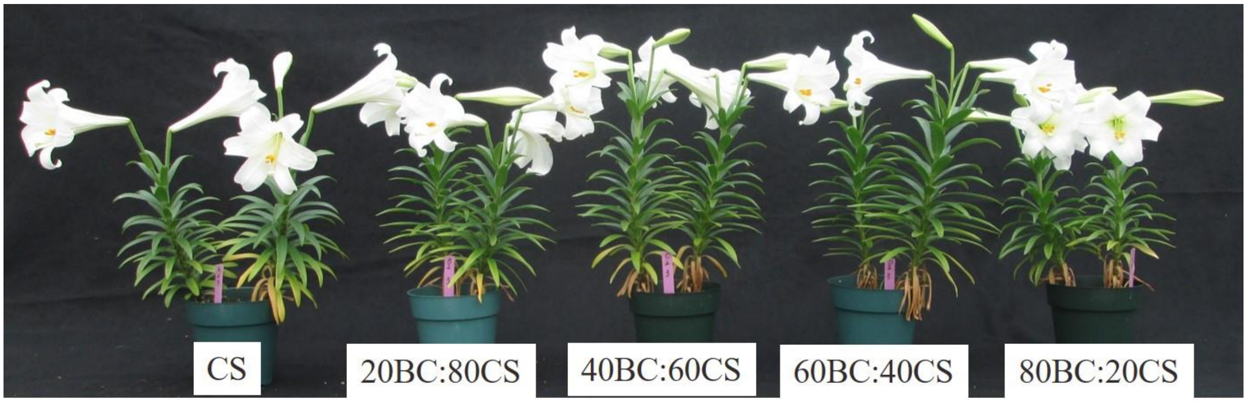

Figure 4. Easter lily grown in peat-based commercial substrate (CS), and pine wood biochar (BC):PB mixes (numbers indicate the percentage by volume).

SUGARCANE BAGASSE BIOCHAR (SBB)

Sugarcane bagasse biochar has similar low pH as PBC (Table 1), however, the SBB particles are much smaller than PBC, resulting in much higher container capacity and lower air space. So trials with SBB did not include peat-based commercial substrate, but instead, bark-based commercial substrate was used. There's still significant portion of peat in the bark-based substrate, but bark-based substrates generally have higher air space. In a trial including 50% SBB, 70% SBB and 50% HB, both tomato and basil plants in biochar mixes had similar growth index and yield, compared to bark-based CS. It is possible that plants in SBB mixes might perform better than bark-based CS if the biochar mixes were mixed with bark alone, as high air space of bark may be complementary to the SBB with low air space.

MIXED HARDWOOD BIOCHAR (HB)

Challenges of using HB in container substrate are the high pH and EC (Table 1). Its container capacity and air space are within or close to the recommended range. Substrate components of finer particle sizes, including vermicompost and chicken manure compost, were used in HB trials.

In one trial, 5%, 10%, 15% and 20% vermicompost were mixed with 20%, 40%, 60% and 80% HB with the rest being commercial peat-based substrate. Basil plants grown in any of the 16 HB mixes performed equally to or better than the commercial substrate. All the tomato plants grown in HB mixes had higher or similar growth index and total dry weight compared to the control.

Chicken manure compost is a much cheaper resource than vermicompost. In another trial, 5% vermicompost or chicken manure compost was mixed with 60%, 70%, 80%, or 90% of HB with the rest being peat-based commercial substrate. Basil plants in 60% and 70% HB:vermicompost mixes had similar total dry weight compared to control. Tomato plants in all HB mixes (with vermicompost or chicken manure compost) had similar growth index compared to control. Chicken manure compost had high salt level and EC. Basil plants had low salt tolerance while tomato plants had high tolerance. This may explain why tomato plants performed well in more HB mixes (especially those with chicken manure compost), compared to basil plants. So chicken manure compost would not be recommended for salt sensitive plants.

DISCUSSION

Biochar is not for all growers. But for growers with close and cheap access to biochar, it is worth of a trial to include biochar in their growing media. Although two of the three biochars in our trials had low pH, most biochars have high pH. Addition of high-pH biochars could reduce or eliminate lime to increase pH of bark or peat. The huge surface area of biochar may provide greater habitat for microbes, which deserve further investigation.

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