Research Note

USE OF BIOCHAR FROM NON-NATIVE TREES AS A GROWING MEDIA COMPONENT FOR BASIL[1,2]

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Biochar has been used with favorable results as a soil amendment and as part of a growing media mix (Sax and Scharenbroch, 2017). Biochar is a type of char with a high concentration of minerals and carbon (C) that is produced from biomass in a low oxygen environment at temperatures greater than 350° C using a process called pyrolysis (Smebye et al., 2017). Some processes to produce biochar use earth mound kilns, flame curtain kilns, retort kilns with off-gases combustion, pyrolytic cook-stoves, and gasifiers combined with electricity production (Smebye et al., 2017). One method of producing biochar that has shown promising on-farm results is the *kon-tiki* flame curtain kiln (Cornelissen et al., 2016), which pyrolyzes the material layer by layer in a conical metal kiln. The layers are pyrolyzed by controlling the rate at which material is fed into the kiln so that smoke and emissions are controlled; smoke appears when too much material is fed into the kiln, and ash is produced when not enough material is fed into the kiln (Cornelissen et al., 2016). This biochar production method is relatively simple and affordable; the fire is safely contained in the instrument and is suitable for producing high quality biochar in small amounts for use on small farms and in gardens (Schmidt and Taylor, 2014).

Some of the benefits of biochar in the growing media of potted plants are increases in organic carbon, pH, cation exchange capacity (CEC), water retention, and plant-available water (Gravel et al., 2013; Headlee et al., 2013; Scharenbroch et al., 2013; Sax and Scharenbroch, 2017). In addition, biochar can reduce soil contaminants and sequester soil C (Bair et al., 2016), and as part of growing media, it can suppress plant pathogens. Zwart and Kim (2012) found that biochar mixed with peat moss can significantly decrease the progression of *Phytophtora* in tree seedlings of *Quercus rubra* and *Acer rubrum*. The authors suggested that biochar can induce resistance by promoting beneficial organisms, and by reducing levels of toxic compounds.

The use of biochar as part of a potting mix can also reduce the amount of peat moss and vermiculite needed to grow plants (Headlee et al., 2014; Margenot et al., 2018; Yu et al., 2019). This is of great importance since peat moss extraction is not a sustainable practice. Yu et al. (2019) found that basil and tomato seedlings grown in tree-biochar and peat moss had similar germination rates and biomass as seedlings grown in peat

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moss alone. Another benefit of biochar is that it can reduce the volume of vegetative waste collected after a storm or hurricane and transform it into manageable material. Clearly, biochar production could be a solution to excess vegetative material, much of which is comprised of non-native tree species. In addition, biochar production offers an alternative use of woody plants that do not have commercial value. The objective of our research was to evaluate the growth of basil (*Ocimum basilicum*) in a propagating media containing different biochar types and concentrations produced from locally available non-native trees. Basil was selected to test the biochar as part of the growing media because basil has a short growing cycle and can be grown in pots.

Dry wood branches of diameters not bigger than 7.6 cm were collected from Caribbean pine (*Pinus caribaea*), African Tulip tree (*Spathodea campanulata*) (Tulipan), and Albizia tree (*Albizia procera*) at the Corozal Agricultural Experiment Substation in Puerto Rico. The branches were cut to lengths between 30.5 and 45.7 cm. All the wood was left to dry until it reached 25% moisture or less. The biochar was produced using a steel Kon-Tiki conical kiln 93 cm in height, 150 cm diameter at the rim, 82 cm diameter at the base, with a side angle of 70° and total volume of 1,000 L (Finger Lakes Biochar, NY). The Pine I biochar was produced at temperatures between 200 and 840° C with a mean production temperature of 617° C; Pine II biochar was produced at temperatures between 240 and 860° C with a mean production temperature of 625° C; Tulipan biochar was produced at temperatures between 450 and 930° C with a mean production temperature of 710° C; and Albizia biochar was produced at temperatures between 440 and 685° C with a mean production temperature of 560° C.

In pyrolysis, higher temperatures (>500° C) are associated with the degradation of lignin and other types of highly resistant organic matter (Tomczyk et al., 2020). Resins can also affect the caloric value and burning temperature of wood; for example, pines tend to have higher resin content than other woods, increasing the burning temperatures (Mercker and Taylor, 2020). Wood density can also affect burning temperatures; higher wood densities are associated with higher burning temperatures (Yazdani et al., 2020). Tulipan wood (270 kg/m^3) is much less dense than Acacia (640 to 880 kg/m^3) and Pine wood (605 kg/m^3) (Lugo et al., 2011; Rojas-Sandoval, 2016). However, in this experiment, Tulipan burned at a higher temperature than the other wood types. The airflow and ventilation during burning could explain the higher temperature. The porous nature of the Tulipan wood and its arrangement in the kiln may have produced more airflow during the biochar production, resulting in higher temperatures compared to the other woods (Husbands and Cranford, 2019).

The amount of wood added to the kiln was carefully controlled to reduce ash production to a minimum. Once the biochar production was completed, the remaining fire was extinguished by adding water. The biochar was left to dry, ground using a hand mill, and sieved through a 2-mm mesh. The biochar was produced from two different burns with pine branches (Pine I and Pine II), one with Tulipan and one with Albizia branches. Samples of each biochar were sent to the Soil Control Lab (Watsonville, CA)[5] for a complete International Biochar Institute (IBI) Test (IBI, 2015) (Table 1). The standardized IBI Test describes biochar as a soil amendment.

The biochar was mixed with Promix LP15 (85-95% Sphagnum peat moss and limestone for pH adjustment). The test of the biochar and Promix mix to grow basil (*Ocimum basilicum*) was performed in two different greenhouse trials. In the first trial, we

[5]Company or trade names in this publication are used only to provide specific information. Mention of a company or trade name does not constitute an endorsement by the Agricultural Experiment Station of the University of Puerto Rico, nor is this mention a statement of preference over other equipment or materials.

TABLE 1.—*Characterization of Pine I, Pine II, Tulipan and Albizia biochars.*

Analysis	Pine I	Pine II	Tulipan	Albizia
Moisture (% wet wt)	26.30	26.40	56.80	8.60
Bulk Density (g/cm^3)	0.33	0.29	0.25	0.28
Organic Carbon (% of dry mass)	86.50	89.10	44.20	51.80
Hydrogen/Carbon (H:C) (Molar ratio)	0.23	0.25	0.42	0.44
Total Ash (% of dry mass)	6.00	6.80	33.60	28.30
Total Nitrogen (% of dry mass)	0.59	0.51	0.36	0.66
pH	9.20	8.90	10.20	10.0
Electrical Conductivity (dS/m)	0.611	0.348	4.67	1.16
Total K (mg/kg)	5,371.00	3,314.00	27,399.00	22,850.00
Total P (mg/kg)	1,279.00	316.00	15,350.00	5,569.00
NH_4-N (mg/kg)	2.80	2.20	4.20	4.30
NO_3-N (mg/kg)	2.50	1.50	9.30	0.70
Organic N (mg/kg)	5,847.00	5,128.00	3,547.00	6,611.00
Fe (mg/kg)	1,400.00	1,580.00	1,567.00	4,125.00
Mn (mg/kg)	280.00	281.00	172.00	111.00
Na (mg/kg)	1,043.00	550.00	1,649.00	703.00
Liming neutralizing value[1] (% of $CaCO_3$)	8.80	6.30	43.10	36.90
Carbonates[2] (% of $CaCO_3$)	4.10	2.70	38.90	25.10
Butane Activity (g/100g dry)	5.70	6.00	2.00	2.20
Surface Area Correlation (m^2/g dry)	316.00	324.00	195.00	204.00
Volatile Matter (% dry weight)	13.20	13.00	30.50	29.70

[1]Liming neutralizing value as compared to percentage of $CaCO_3$.
[2]Percentage of carbonate carbon in the biochar represented as a percentage of $CaCO_3$.

tested the Pine I, Pine II and Tulipan biochar and biochar mixes, and for the second we tested only the Albizia biochar mixes. Mixes of biochar and Promix were calculated on a dry weight (w/w) basis. The treatments for the first trial were: Control (100% Promix), 10% Pine I biochar (90% Promix + 10% Pine Biochar), 25% Pine I biochar (75% Promix + 25% Pine Biochar), 10% Pine II biochar (90% Promix + 10% Pine Biochar), 25% Pine II biochar (75% Promix + 25% Pine Biochar), 10% Tulipan biochar (90% Promix + 10% Tulipan Biochar), 25% Tulipan biochar (75% Promix + 25% Tulipan Biochar). The treatments for the second trial were: Control (100% Promix), 10% Albizia biochar (90% Promix + 10% Albizia Biochar), 25% Albizia biochar (75% Promix + 25% Albizia Biochar).

The biochar - Promix mixes were used to fill small plant pots (7.6 cm diameter x 7.6 cm height). Ten pots (repetitions) of each mixture were included in the study, and three basil seeds were planted per pot. Germination was recorded one week after planting and only one seedling was left per pot. During the first week, a dose of 0.22% Imidacloprid was applied to control aphids. Four milliliters of liquid fertilizer (20-20-20) was applied once a week using a hand sprayer. Two milliliters was applied directly to the plant, and 2 ml was applied to the growing media. Plants were irrigated in the morning and evening for 10 minutes using sprinkled irrigation. The number of leaves and plant height were measured once a week until harvest. After 40 days, the plants were harvested to determine fresh biomass and oven-dry biomass (55° C for 72 hours). Statistical analyses were performed using analysis of variance (ANOVA) (InfoStat). Means comparisons were performed using Tukey tests and an alpha of 0.05.

The results for the first trial showed that the biochar treatments did not significantly affect basil germination compared to Control (Table 2). However, plant height, number of leaves, wet biomass, and dry biomass at harvest were all significantly different among treatments. The 10% Tulipan biochar was significantly lower than other treatments, except for 25% Tulipan, for height, number of leaves, dry and wet biomass (Table 2). Meanwhile, 25% Tulipan biochar compared to Control in plant height, with 10% Pine, 25% Pine and Control in wet biomass, and 10% Pine and Control in dry biomass. In addition, 25% Pine II biochar had significantly greater dry biomass than Control and both Tulipan biochar treatments (Table 2). The pH analysis of the growing media showed significantly greater values in both Tulipan biochar treatments compared to the Control (Table 3).

There was no significant difference among treatments for EC (Table 3), although the Tulipan biochar had very high EC compared to the other biochars (Table 1). High EC in biochar has been associated with soluble minerals in the biochar (Domingues et al., 2017). In particular, the Tulipan had greater total K and P (27,399 and 15,350 mg/kg, respectively), and ash (33.6% of dry mass) than the other biochars (Table 1). In the biochar analysis, ash is the residual material that remains after the biochar is burned. Greater mineral content is correlated with higher ash content and higher biochar production temperatures, which is the case of the Tulipan biochar (Chaves-Fernandes et al., 2020). However, this higher mineral content, especially of K and P in Tulipan biochar, may not have played a significant role in increasing plant growth, as all treatments received fertilizer applications.

The results of the second trial showed no significant differences between the Control and the Albizia biochar treatments (10% and 25% Albizia biochar) for germination, height, number of leaves, and wet and dry biomass (Table 4). However, the 10% Albizia biochar had significantly greater pH than the Control (Table 5).

In both trials, there were no significant differences in plant germination (Tables 2 and 4). Germination is important to characterize biochar because some biochars can inhibit seed germination. Results showed that Pine and Albizia biochars can partially substitute for peat moss in growing media. However, Tulipan biochar treatments (10% and 25% biochar) resulted in smaller plant growth; this could be related to the greater pH in the Tulipan biochar compared to other biochars (Table 1). The optimum media pH values for basil growth are between 6 and 7.5 (Hamasaki et al., 1994). In the case of the Tulipan biochar treatments both pH values were higher than 8.0 (Table 3). Also, Tulipan and Albizia biochars had higher H:C ratios, ash content and inorganic nutrients compared to the Pine biochars (Table 1). These higher val-

TABLE 2.—*Plant growth parameters for the first trial of biochar application.*

Treatment	Germination (%)	Height (cm)	Num. of leaves	Biomass wet (g)	Biomass dry (g)
Control	87	29.0 ab[1]	16.0 a	10.1 ab	1.1 bc
10% Pine I	83	30.0 a	16.2 a	10.5 ab	1.4 ab
25% Pine I	93	34.6 a	15.7 a	11.0 a	1.5 ab
10% Pine II	77	32.4 a	16.1 a	10.8 ab	1.3 abc
25% Pine II	87	35.6 a	17.0 a	12.5 a	1.9 a
10% Tulipan	93	17.5 c	11.2 b	3.4 c	0.4 d
25% Tulipan	67	20.4 bc	14.1 ab	5.9 bc	0.6 cd
Pr>F	0.6986	<0.0001	0.0031	<0.0001	<0.0001

[1]Pair-wise comparisons were performed using Tukey LS means. Means with different letters within columns are significantly different (α=0.05)

TABLE 3.—*Growing media electrical conductivity and pH for the first trial of biochar application.*

Treatment	EC dS/m	pH
Control	0.199	7.50 b[1]
10% Pine I	0.226	7.69 ab
25% Pine I	0.189	7.80 ab
10% Pine II	0.316	7.74 ab
25% Pine II	0.273	7.64 ab
10% Tulipan	0.307	8.02 a
25% Tulipan	0.231	8.09 a
Pr>F	0.0474	0.0047

[1]Pair-wise comparisons were performed using Tukey LS means. Means with different letters within columns are significantly different (α=0.05).

ues in ash content and inorganic nutrients are usually related to higher production temperatures (Tomezyck et al., 2020; Almutairi et al., 2023). Although Tulipan had greater biochar production temperatures than the other biochars, the Albizia biochar had production temperatures similar to the Pine biochars. In the case of H:C ratios, lower values, such as in Pine biochar, indicate higher aromatic structures, more stable biochar and potentially long-term stability for carbon sequestration (Tomezyck et al., 2020). In terms of volatile matter, the higher values of Tulipan and Albizia biochars could affect the ion sorption capacity of the biochar because the volatiles occupy space that would be available for ion absorption. Also, higher volatile matter values could affect plant growth as some volatiles could be phenols that affect root growth (Tomezyck et al., 2020). The greater nutritional content in both the Tulipan and Albizia biochars (Table 1) may not have significantly affected plant growth since fertilizer was supplied to the plants. Nutrient contents in biochar are correlated to the nutrient contents of the original wood (Ippolito et al., 2020); both Tulipan and Albizia wood probably had greater nutrient content than the Pine wood. Future studies should investigate other possible causes for lower plant growth in growing media mixed with Tulipan biochar since Tulipan is an abundant non-native species with few alternative uses in Puerto Rico. Its higher liming effect and nutrient content make Tulipan biochar better suited as a soil amendment to increase soil pH in acid soils (Table 1). African Tulip is a widely distributed tree species in Puerto Rico that can thrive in many different substrate and soil types, including weathered-soils (Abelleira-Martínez, 2019. In conclusion, the use of biochar from some non-native tree species (Pine and Albizia) in Puerto Rico could decrease the use of peat moss in

TABLE 4.—*Plant growth parameters for the second trial of biochar application.*

Treatment	Germination (%)	Height (cm)	Num. of leaves	Biomass wet(g)	Biomass dry (g)
Control	93	20.3	15	5.8	0.9
10% Albizia	73	19.6	13	3.8	0.6
25% Albizia	83	19.4	14	4.0	0.6
Pr>F	0.1005	0.9560	0.7402	0.3514	0.2465

TABLE 5.—*Growing media electrical conductivity and pH for the second trial of biochar application.*

Treatment	EC dS/m	pH
Control	0.206	7.60 b[1]
10% Albizia	0.207	8.11 a
25% Albizia	0.254	7.93 ab
Pr>F	0.2494	0.0089

[1]Pair-wise comparisons were performed using Tukey LS means. Means with different letters within columns are significantly different (α=0.05).

plant growing media; however, high pH values and salinity potential might limit the use of Tulipan biochar when combined with peat moss mixes that include limestone for pH adjustment. Hence, Tulipan biochar may be better suited as a soil amendment in acid soils.

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