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Biochar in Propagation Substrates: Sustainable solution or Impractical Idea?

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Summary

Identifying sustainable horticultural substrates is critical, but what does sustainability really mean? Biochar is perceived as sustainable in many settings, but does it deserve this status in plant propagation? I conducted experiments with coconut-shell biochar to assess its suitability in seed propagation and vegetative propagation substrates. Biochar performed well as a substrate amendment in my experiments. However, the costs associated with the biochar make classifying it as sustainable a nuanced discussion.

INTRODUCTION

Horticultural substrates need to be very consistent and high performing, especially in propagation settings (Davies et al., 2018). Traditional propagation substrate components, such as sphagnum peat and perlite, are increasing in cost and subject to supply-chain interruptions (Jackson, 2022). In addition, the sustainability of peat has become a controversial question.

Sustainability is not just an environmental issue; it is also economic and social (Purvis et al., 2019). Growers are looking for economically and environmentally sustainable substrates. Expanding the list of effective and proven substrates would allow growers to respond to supply issues and select sustainable options. Biochar, pyrogenic carbonaceous material that may be used as a growth medium for plants, has drawn attention as a promising candidate for the horticulture industry (Dumroese et al., 2011; Vaughn et al., 2013). Over the past 6 years, I have conducted seed- and vegetative-propagation experiments with herbaceous plants in substrates amended with coconut-shell biochar. Data from these experiments were analyzed with the appropriate test for the design, in most cases analysis of variance (ANOVA) with post-hoc Tukey HSD Testing. Test assumptions were checked, and the threshold for rejecting a null hypothesis was $P \leq 0.05$.

Biochar in These Experiments

The biochar used in my experiments came from a commercial supplier (Bay Area Biochar, Concord, CA). It was made from coconut-shell feedstock, which underwent fast pyrolysis at ~ 700 °C. The components were then ground and acidified to a pH of 6.4. The chemical and physical properties of the biochar was relatively consistent in the batches used in these experiments (Figure 1, Table 1). The raw material cost of the biochar was approximately three times that of coarse perlite or sphagnum peat by volume.

Table 1. Nutrient and particle-zize analyses of the coconut-shell biochar used in seed germination and vegetative propagation experiments in this report. Data are from a well-mixed sample submitted to a commercial laboratory (Waypoint Analytical, Anaheim, CA).

Nutrients (ppm)		**Particle Size (dry weight)**	
		Screen (mm)	*Passing (%)*
Nitrogen (N)	17	9.5	100.0
Phosphorus (P)	104	6.4	99.8
Potassium (K)	2831	4.8	99.4
Calcium (Ca)	248	2.4	97.7
Magnesium (Mg)	116	1.0	37.5
		0.5	15.4

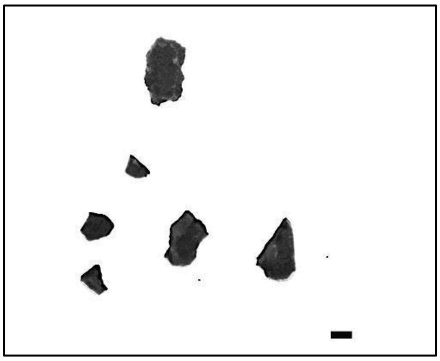

Figure 1. A typical coconut-shell biochar sample, showing particle shapes and sizes (bar = 1 mm).

Seed- Propagation Experiments

A completely-randomized-design experiment was conducted to test biochar effects on seed germination in a laboratory setting. The experimental unit was a Petri dish, with a base substrate of sphagnum peat and fine perlite (1:1, v/v) amended with biochar (0, 10, 20, 40, 80% v/v), containing 20 seeds. *Coreopsis grandiflora*, *Eschscholzia californica*, *Lavandula angustifolia*, and *Rudbeckia fulgida* were the plant species tested. Each species was treated as a separate experiment (n = 10). Over a 14-day germination period, the only significant difference that occurred was a reduction of *Eschscholzia* germination in 80% biochar compared to the other treatments. The other species showed no significant germination differences related to biochar.

Following the lab study, two seed germination and growth trials were conducted in two germination rooms. The experiments were randomized complete block designs; each experimental unit was a 4-inch container with 10 seeds. The plant seeds were *Coreopsis grandiflora*, *Eschscholzia californica*, and *Leucanthemum* × *superbum*, with each species treated as a separate experiment (n = 10). The base substrate was a modified Cornell germination mix (sphagnum peat and fine vermiculite, 1:1, v/v) amended with biochar (0, 5, 10, 20, 40%, v/v). Root length and shoot length were measured. Growth of the seedlings increased slightly with added biochar content, but despite being statistically significant, the differences had little practical significance. The results from these experiments were published in 2018 (Hoover, 2018).

In my lab and germination room testing, coconut-shell biochar performed well as a propagation substrate component. Germination was mostly not affected by biochar incorporation, with just one instance of a slight negative effect at 80% biochar in one species. Growth rates were slightly increased in seedlings when biochar was added; however, this positive effect was minimal.

Vegetative propagation experiments

Herbaceous cuttings were stuck in a sphagnum peat and coarse perlite (1:2, v/v) substrate amended with biochar (0, 10, 20, 40, 80%, v/v, **Fig.2**), and then placed a mist house. Randomized complete block designs were used, with the species being treated as separate experiments (n = 15).

The experimental unit was a 2.5-inch rose pot containing one cutting. Most of the species were repeated in a second round of experiments (n = 10). The species tested were: *Achillea* hybrid, *Ajuga reptans*, *Coreopsis verticillata*, *Iberis sempervirens*, *Leucanthemum* × *superbum*, *Phlox subulate,* and *Salvia* × *sylvestris*. The cuttings were evaluated after recommended rooting periods (21 to 36 days, depending on the species).

Figure 2. Sphagnum peat and coarse perlite (1:2, v/v) substrate amended with coconut-shell biochar at 0, 10, 20, 40, and 80% (left to right, v/v, bar = 1 cm).

I removed cuttings from containers, washed the roots, and assigned each cutting an adventitious rooting rating (0 = cutting dead, 1 = cutting alive but no root development, 2 = minimal root development, 3 = moderate root development but insufficient for transplanting, 4 = good root development and sufficient for transplanting, 5 = optimal root development). Roots were then excised and scanned (Epson Perfection V19). I used ImageJ to analyze root two-dimensional area, first-order root count, and primary root length in the scans. Biochar amendment of 0, 10, or 20% had no measured effect on root growth, though some slight positive trends were visible. Biochar at 40 or 80% either had no effect or a negative effect on root growth. The most pronounced effect was observed at 80% biochar, when many species had significantly more first order roots than the lower biochar treatments, yet those primary roots were shorter and less developed. Results from these experiments were shared via a presentation in 2017 (Hoover, 2017).

Follow-up experiments were conducted, matching the biochar particles with sand particles. Sand amendment did not affect rooting in the same fashion as biochar amendment, suggesting that the rooting difference was chemical or related to water and oxygen levels, rather than physical shape of the particles. Results from these experiments were presented via a poster in 2018 (Hoover and Mattlin, 2018).

I also conducted two experiments with herbaceous cuttings that involved biochar and drench treatment with indole-3-butyic acid with potassium salts (K-IBA). Cuttings were stuck in a sphagnum peat and coarse perlite (1:2, v/v) substrate amended with biochar (0, 10, 20, 40, 80%, v/v, Figure 2). I then applied 0, 1,000, or 3,000 IBA in either talc powder form or as a drench. Randomized complete block designs were used, with the species being treated as separate experiments (n = 20). The experimental unit was a 2.5-inch rose pot containing one cutting. The species tested were *Salvia* × *sylvestris* and *Scabiosa columbaria*. The cuttings were evaluated after 28 days. Biochar amendment at 80% negatively affected root development (**Table 2**), but low rates of biochar had no negative affect. Biochar presence did not influence K-IBA drench efficacy.

Table 2. Root measurement means of *Scabiosa* and *Salvia* cuttings in sphagnum peat and perlite substrate (1:2, v/v) amended with coconut shell biochar. Adventitious Root Rating (0 = cutting dead, 1 = cutting alive but no root development, 2 = minimal root development, 3 = moderate root development but insufficient for transplanting, 4 = good root development and sufficient for transplanting, 5 = optimal root development). Means in a column that do not share a letter are different according to a Tukey HSD test, $p \leq 0.05$, n = 20).

	Scabiosa		Salvia	
Biochar (%, v/v))	Rating	Root Area (cm^2)	Rating	Root Area (cm^2)
0	3.6 a	3.4 ab	3.0 a	3.6 a
10	3.5 a	3.4 ab	3.1 a	3.4 a
20	3.8 a	4.6 a	2.6 ab	2.7 a
40	2.8 b	2.3 bc	2.7 ab	2.8 a
80	2.0 c	0.8 c	2.2 b	0.9 b

In the vegetative propagation experiments, I saw favorable rooting responses when biochar was incorporated at rates of 20% or below. At 40% biochar, the response was either neutral or negative. The highest rate tested, 80% biochar, resulted in poorly developed roots.

CONCLUSION

The coconut-shell biochar in these studies had no negative effect on germination or rooting of cuttings when incorporated at rates up to 20%, and in some cases as high as 40%. While these outcomes are encouraging, they must be considered along with the financial cost associated with the biochar. At this time, the coconut-shell biochar used in my experiments could not be considered sustainable on an economic level. It is too expensive to displace other substrate options. On an environmental level the feedstock acquisition, processing, and shipping involved in making high quality biochar may also bring sustainability claims into question. While the biochar in these studies was very consistent, the product is expensive. Biochar may be created onsite or sourced from sellers, and as a general product it is very variable, spanning a large range of physical and chemical properties. This unpredictability means caution is required when predicting plant growth responses. Trials are recommended prior to large-scale adoption. If biochar production can become cost effective, with favorable porosity and chemical properties, it may have a future in propagation substrates.

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