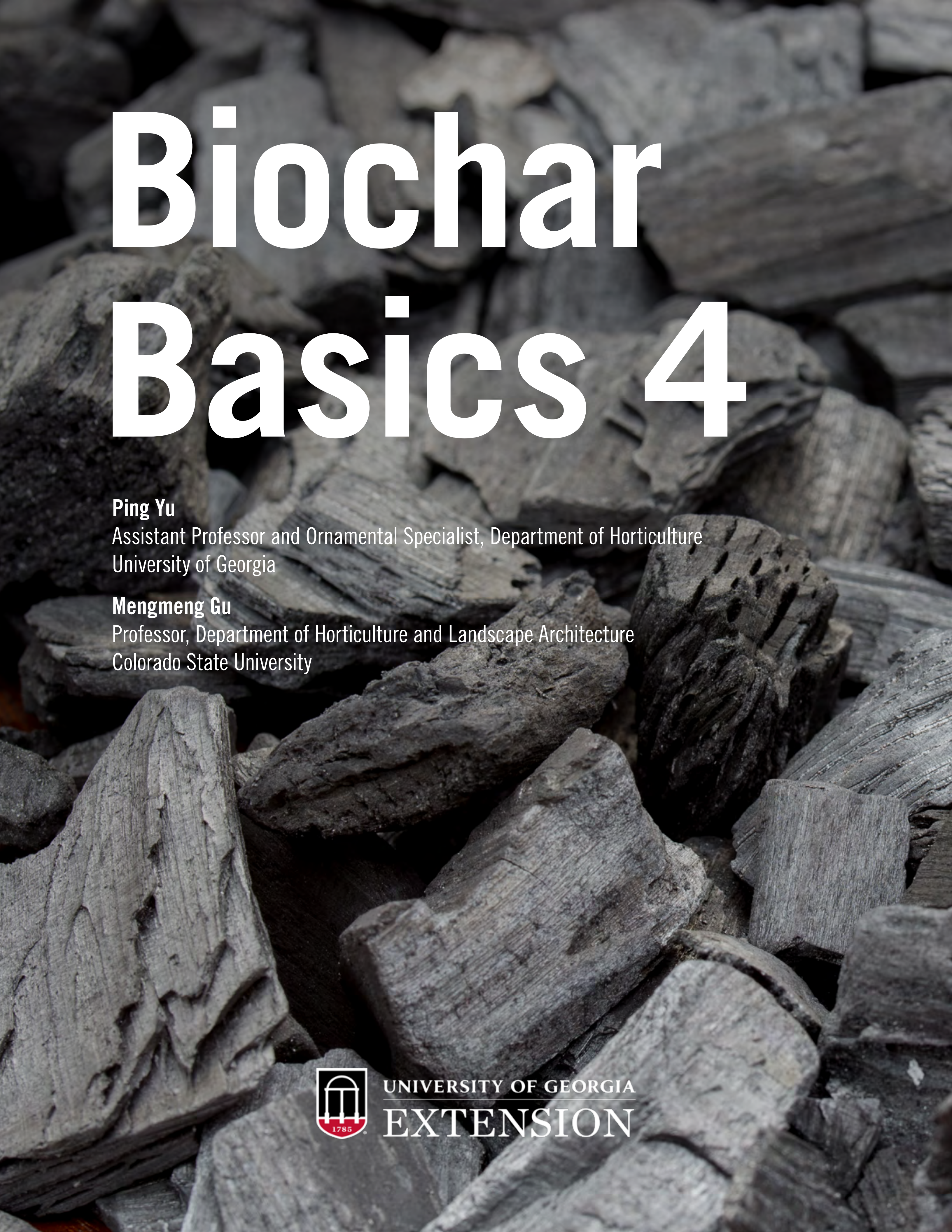

Biochar Basics 4

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Part 4: Biochar Properties and Making the Right Biochar Mix

Container substrates must fulfill several functions for plant growth: create a suitable environment for root growth, physically support the plant, hold nutrients and water, and enable gas exchange between the roots and the atmosphere. Suitable physical and chemical properties of container substrates facilitate these functions.

In this last section of the *Biochar Basics* series, we discuss biochar's physical and chemical properties and provide a guide for producers who may want to make their own biochar mixes.

Physical Properties

The physical properties of container substrates include air space (%), container capacity (%), total porosity (%), bulk density (g/cm^3), and water holding capacity. *Air space* measures the proportion of air-filled large pores (*macropores*) after drainage. Air space influences gas exchange and water holding capacity. *Container capacity* measures the maximum percentage volume of water a substrate can hold after drainage. *Total porosity* equals container capacity plus air space, and it measures the substrate volume that holds water and air. *Bulk density* measures how much one unit of the substrate weighs. *Water holding capacity* measures the container substrate's ability to physically hold water against gravity; its maximum value equals container capacity (Huang, 2018).

As mentioned in Part 1 of this publication, biochar can be derived from various feedstocks, processed under different pyrolysis temperatures, and subjected to various pre- or posttreatments, which can lead to dissimilar physical properties that affect a container substrate's physical properties. Adding biochar may affect air space, container capacity, total porosity, and bulk density with variable effects. For instance, substituting peat moss with 50% green waste biochar (by volume) did not affect total porosity and container capacity, but significantly decreased air space, which was still in the optimal range (15%–30%) for container substrates. Similarly, a peat-moss-based substrate's total porosity decreased with the increased addition of pelleted biochar (Dumroese et al., 2011). However, adding deinking sludge biochar increased the total porosity and air space of the container substrate. The impacts of biochar on a substrate's air space, container capacity, and total porosity have been reported to vary, with no specific trends emerging.

Unlike the varied effects of biochar on air space, container capacity, and total porosity, the impact of biochar on bulk density and water holding capacity has been more consistent. Biochar has higher bulk density than commonly used substrate components such as peat moss and vermiculite. Thus, replacing a certain percentage of peat moss and/or vermiculite with biochar can increase the overall bulk density of substrates. The addition of biochar can also increase the water holding capacity of a soilless substrate. For instance, a proper mixture of 25% pelleted biochar and 75% peat (by volume) was shown to hold more water than 100% peat substrates (Dumroese et al., 2011).

Chemical Properties

Container substrate chemical properties include electrical conductivity (EC) and pH. The EC is an index of soluble salt content and measures all the electrically charged ions dissolved in a solution. pH is a measure of the acidity or alkalinity of a substrate.

The chemical properties of biochar vary widely and the addition of biochar to a container substrate can have different effects on the chemical properties of the container substrate. The addition of biochar to peat-moss-based substrates has been shown to increase the overall EC of those substrates (Rahman et al., 2016; Tian et al., 2012). In general, biochar has been reported to increase the pH of soilless substrates because of its alkalinity. However, the pH of biochar ultimately depends on the feedstock and pyrolysis temperatures. Under certain conditions with certain feedstocks, biochar may be acidic. The pH of biochar made from pyrolysis of oak and switchgrass at 250 °C was 3.5, while the pH was 5.9 when made from switchgrass alone (Novak et al., 2009). Generally, the lower the temperature used in pyrolysis, the lower the pH in the resulting biochar.

The addition of biochar to a container substrate may affect nutrient availability as well. Some forms of biochar can serve as a source of phosphorus (P) and potassium (K), increasing P and K availability and potentially reducing the total amount of fertilizer needed for plant growth. Pretreatment of biochar feedstock bark with tannery slurry as an alkaline treatment also resulted in greater ammonium absorption capacity than in untreated feedstock (Hina et al., 2010). However, another study found that available nitrogen and K were decreased after the addition of green-waste biochar to peat substrates (50% volume per volume; Tian et al., 2012). Biochar in a pelletized form using soybean-based bioplastics also has been shown to be a source of nutrients in a soilless substrate.

Make Your Own Biochar Mix

So how would you guarantee success when using biochar as a container substrate for plant production? When using biochar mixes, you must couple the right biochar with the right plant (based on the pH and EC tolerance). Choose a biochar with suitable properties (pH, EC, particle size, etc.) and be careful with the amount of biochar added. For example, if you were growing blueberries, hydrangeas, or azaleas, which require an acidic substrate, you wouldn't want to grow them in a substrate with a high percentage of alkaline biochar. By volume, 80% is the highest percentage of biochar successfully being used for container plants.

We compared the physical and chemical properties of the biochar we tested with some commonly used commercial mixes. The recommended chemical and physical properties for those container substrates are listed in Table 4.1. While biochar may have different properties, many can successfully be used as container substrates for plant growth by mixing with other components.

There are two main ways of creating your biochar mix:

Option 1: Mix with a commercial substrate. A simple way to make the target biochar work is to mix it with commercial mixes that contain components such as perlite and/or vermiculite, lime, a wetting agent, fertilizer charge, etc.

Option 2: Create your own mix. You can mix biochar with other components such as peat moss, perlite, pine bark, etc.

No matter which way you choose to create your biochar mix, particle size is important. If you choose Option 1 and your biochar is coarse-textured (with a relatively larger particle size), think about mixing it with a peat-moss-based commercial substrate to bring down the particle size of the final mix. If, however, your biochar is fine-textured (with a relatively smaller particle size), think about mixing it with a pine-bark-based commercial substrate to increase the particle size of the final mix. The same concept applies to Option 2. When the chosen biochar is relatively coarse-textured such as a mixed hardwood biochar, mixing it with other components with a fine texture, such as vermiculite and peat moss, would ensure appropriate particle size in the final mix.

Besides particle size, another important consideration is pH. A pH range of 5.4–6.5 is suitable for most greenhouse crops; acidic biochar used in greenhouses usually falls within the suitable pH range (5.4–5.9) for use as a container substrate. Alkaline biochar, however, can have a high pH which may make nutrients less available to plants and lead to adverse effects on plants. A way to solve this problem is to mix it with acidic components such as peat moss. Theoretically, alkaline biochar also can be mixed with acidic biochar if their particle sizes can compensate for each other, but further research is necessary to support this concept.

The EC of biochar can vary as well, but normally those used in greenhouse studies had a relatively low EC because they were made from ligneous feedstock such as wood, bark, sugarcane bagasse, etc. A lower EC may allow you to add more fertilizer before salt damage becomes an issue. Research has shown that you may be able to mix a low-EC biochar with nutrient-rich components. Based on our research, the percentage of nutrient-rich components should be low (less than 30% by volume) or else the high EC could cause plant phytotoxicity.

Table 4.1. Properties of Different Container Substrate Components.

Properties and mixes	Total porosity (%)	Container capacity (%)	Air space (%)	Bulk density (g/cm^3)	pH	Electrical conductivity (mS/cm)	Particle size (mm)
Recommend ranges	**50–85**	**45–65**	**10–30**	**0.19–0.7**	**5.4–6.5**	**< 0.75 (seedlings) < 1.5 (general crops)**	—
Pinewood biochar	83	48.6	34.2	0.17	5.4	—	0.59–2
Mixed hardwood biochar	85	60.3	24.4	0.15	10.8–11.8	0.11	67.3% > 2
Sugarcane bagasse biochar	74	66–85	3–9	0.09–0.11	5.9	0.08	0.17 (mean)
Peat moss	83	64	18.9	0.08	4.3–5	—	—
Perlite	92	59	34	0.05	7.3	0.01	—
Vermicompost	75	72	3	0.38	4.8	6.7	89.4% < 2
Chicken manure	64	60	4	0.62	7.5	32.9	89.4% < 2
Peat moss based commercial growing mix	74–78	58–71	3–20	0.09–0.1	—	—	65.2% < 2
Peat moss based commercial propagation mix	71–75	84	15	0.11	6.8	0.07	—
Pine bark based commercial mix	79–97	47–85	12–31	0.15	6.5–6.75	0.18	3–6

Is Biochar Worth Using?

Does it make dollar sense to use biochar as a container substrate for horticultural production? The 2023 prices of commercial peat-moss-based substrates and locally sourced biochar averaged $4.87/ft^3 and $2.22/ft^3, respectively. According to the biochar literature, 20% to 80% of peat moss in a substrate can be replaced with biochar (using 50% as the average) without any negative influence on plant growth or yield.

If you switch some peat moss to biochar, you may save money on media without sacrificing plant production. For example, if a grower uses 1,000 cubic feet of peat-moss-based substrate for container plant production each growing cycle, using biochar mixes at 50% could save approximately $1325 each growing cycle [($4.87/ft^3 - $2.22/ft^3) × 1,000 × 50% = $1,325]—not to mention the potential savings through reduced use of fertilizer, fungicides, and/or pesticides.

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