Assessing biochar as a lime replacement for peat substrates

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Abstract

Peat is used as the base medium in greenhouse production, but its acidic nature requires amendments such as lime to bring the pH up to the recommended ranges of 5.4-6.6 for soilless substrates. Biochar is a sustainable option as a substrate component with varying characteristics of surface area, pH, nutrient supply and water storage. Using less nutrient-rich feedstocks for biochar production has created material with high pH and abilities to neutralize acidic peat. Two different biochars were produced through gasification using pine wood chips (*Pinus taeda* L.) and rice hulls (*Oryza sativa* L.). The resulting biochars had pH values above 8.5 and were assessed as potential lime replacements by pulverizing the biochars to <2 mm to create a powder-form of pine wood biochar and rice hull biochar. These pulverized biochars were amended to a pure peat substrate at rates of 1.78, 3.56, 5.34, or 7.13 kg m^{-3} (3, 6, 9, or 12 lb yd^{-3}). In this pulverized form, the two biochars showed little to no effect on neutralizing the peat's acidity; after seven days the maximum substrate pH attained for both pine wood biochar and rice hull biochar was 4.1. The second study increased the amount of pulverized biochar amendments to 10.69, 12.47, or 14.25 kg m^{-3} (18, 21 or 24 lb yd^{-3}, respectively). Again, the substrate pH for both biochar types did not reach the recommended minimum for substrates (5.4). While it is clear that biochars made from different feedstocks can produce different benefits and results; additions of these two pulverized biochars did not provide the quick, short-term effects needed for greenhouse production.

Keywords: greenhouse production, pine wood chips, pH, rice hulls

INTRODUCTION

Peat is commonly used as a component of soilless substrates for greenhouse production, but its acidic nature requires amendments such as lime to bring the pH up to the recommended ranges of 5.4-6.6 for soilless substrates. Biochar has potential as a substrate component, due to its potential to influence both the physical and chemical properties of soilless substrates. On the physical side, biochar produced from either urban green waste or agricultural/forestry residues has been shown to improve hydraulic conductivity, water retention and increase permanent wilting point when amended to soilless substrates (Dumroese et al., 2011; Cao et al., 2014). From the chemical side there has been a wide range of characteristics reported, from increased cation exchange capacity and exchangeable nutrients in red oak biochar when amended to soilless substrates (Headlee et al., 2014), wide ranges of pH from 5.4 to 10.3 (Spokas et al., 2012; Fornes et al., 2015; Nemati et al., 2015), to having the capability to neutralize acidity caused by both peat and root activity (Bedussi et al., 2015; Blok et al., 2017). All these characteristics together give biochars good potential as a soilless substrate component; however there is a great deal of variability among biochars from different feedstocks and production methods.

Previous work with pine wood biochar and rice hull biochar has shown that both have

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high pH at 8.7 and 9.5, respectively (Judd, 2016). The objective of this paper was to test the ability of these two alkaline biochars produced in a gasifier to replace lime as a neutralizing agent for the acidity of peat. The biochars were treated as lime by pulverizing them to <2 mm to create a powder-form biochar.

MATERIALS AND METHODS

The two types of biochar were produced using a top-lit updraft (TLUD) gasifier technique with two separate feedstocks: pine wood chips and rice hulls. Both feedstocks were charred at a maximum temperature averaging 745°C to produce pine wood biochar (PBC) and rice hull biochar (RBC). Both PBC and RBC biochars were pulverized to <2 mm using a hand mill (4-F hand mill; Quaker City Mill, Philadelphia, PA). The pulverized biochars were visually comparable to a powder-form of biochar, as seen in Figure 1.

Figure 1. (Left) Comparison of biochar produced from pine wood (loblolly; *Pinus taeda*), that was then ground to <2-mm size (right; PBC_p). (Right) Comparison of biochar produced from rice hulls, that was then ground to <2-mm size (right; RBC_p). Centimeter ruler shown in both pictures for size comparison.

The control was 100% peat with no biochar additions. The pulverized pine wood biochar (PBC_p) and rice hull biochar (RBC_p) were blended similarly as a dolomitic lime (#100 mesh) substitute and added to the peat substrate. On July 14, 2015, PBC_p or RBC_p was added to 0.014 m^3 of peat at 1.78, 3.56, 5.34, or 7.13 kg m^{-3}, and each substrate was placed into a clear, resealable plastic bags (#35XE41 1.8mil LDPE; Grainger, Raleigh, NC). The substrates were allowed to equilibrate for 24 h, and pH was then measured daily for the next six days. Three representative samples of 100 mL from each bag were used for the 1:1 dilution method off pH measurement; one part material (100 mL) was mixed vigorously with one part deionized (DI) water and allowed to equilibrate for 15 min.

On July 22, 2015, the experiment was repeated with higher rates of PBC_p or RBC_p addition at 0, 10.69, 12.47, or 14.25 kg m^{-3}. These substrates were measured every 24 h for three days to observe if the higher rates of pulverized biochar would raise the pH of the peat substrate.

RESULTS AND DISCUSSION

Different biochars have shown potential as a replacement for lime in greenhouse substrates, especially with biochars at different particle sizes. For PBC_p, substrate pH was increased initially from 3.78 (control) to only 4.06 (at 7.13 kg m^{-3}; Figure 2). Even after 7 days, the maximum pH attained was 4.12 with the highest rate of PBC_p.

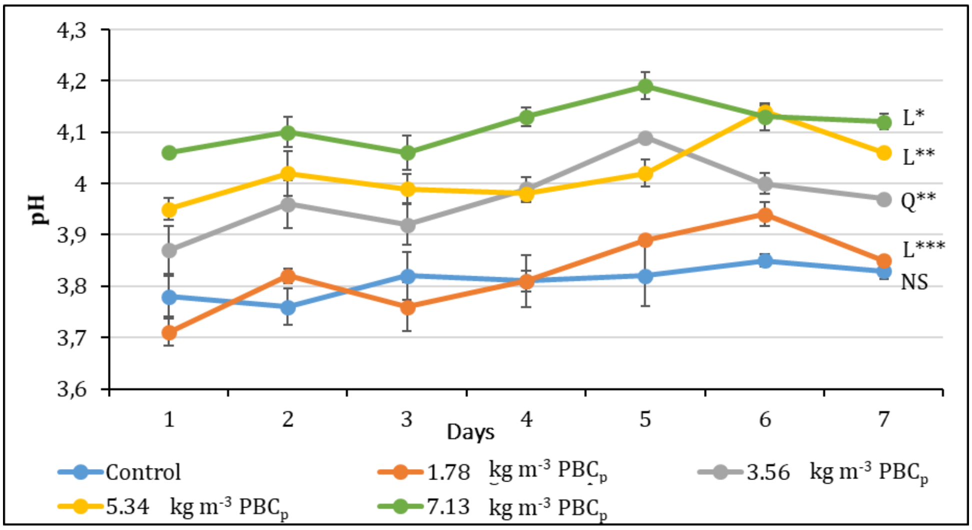

Figure 2. Addition of pulverized pine wood biochar (PBC_p) to peat moss at four different rates (1.78, 3.56, 5.34 or 7.13 kg m^{-3}) and compared to 100% peat (control) with no biochar addition to show effects on pH over time. Error bars represent standard error; non-significant (NS), linear (L), or quadratic (Q) regression of each substrate pH over time, *** represents significant effects when $P \leq 0.001$.

The rice hull biochar had a similar, albeit less effect, ranging from 3.78 (control) to 3.92 (at 5.34 and 7.13 kg m^{-3}) initially with a maximum pH of 4.03 during the 7 day incubation period (Figure 3). All substrates with the additions of PBC_p and RBC_p never reached the recommended pH range for substrates, while also showing a trend of decreasing pH after day 6. At a rate of 1.78 kg m^{-3}, both PBC_p and RBC_p were similar to the control (peat with no additions) at all days with the exception of RBC_p at Day 6. Initially, at day 1, only 5.34 and 7.13 kg m^{-3} rates for PBC_p and RBC_p were different from control and this continued for the rest of the measurement days for PBC_p only.

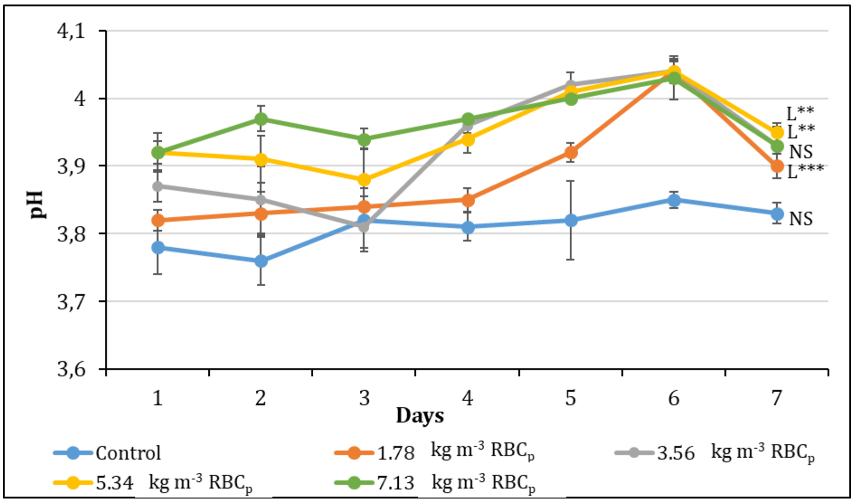

Figure 3. Addition of pulverized rice hull biochar (RBC_p) to peat moss at four different rates (1.78, 3.56, 5.34 or 7.13 kg m^{-3}) and compared to 100% peat (control) with no biochar addition to show effects on pH over time. Error bars represent standard error; non-significant (NS), linear (L), or quadratic (Q) regression of each substrate pH over time, *** represents significant effects when $P \leq 0.001$.

Previous work has shown biochar made from hardwood increased pH to or above the recommended range of 5.4 to 6.6, with smaller particles increasing the pH compared to the larger sizes (Northup, 2013). This was not seen with pulverizing PBC and RBC, although pulverizing the biochars increased the pH of the biochar itself; PBC increased from 8.7 to 9.4 after pulverization, however there was no change in pH for RBC (pH of 9.5) after pulverization. The pH of biochar can change depending on the temperature and air flow through the production system, and Rivas (2015) reported having basic functional groups and no acidic functional groups on the surface of pine wood and rice biochar produced in a similar TLUD gasifier.

Increasing the additions of PBC_p and RBC_p to 10.69, 12.47 and 14.25 kg m^{-3} were then tested, and all substrates with PBC_p and RBC_p had higher pH than the control, but only reached a pH of 4.4 and 4.05, respectively (Figure 4). While the pulverized biochars did not aid in the peat reaching the target pH minimum of 5.4, both the PBC_p and RBC_p did help to stabilize the substrate pH over the 3 days as there was non-significant effects of each substrate pH over time (Figure 4).

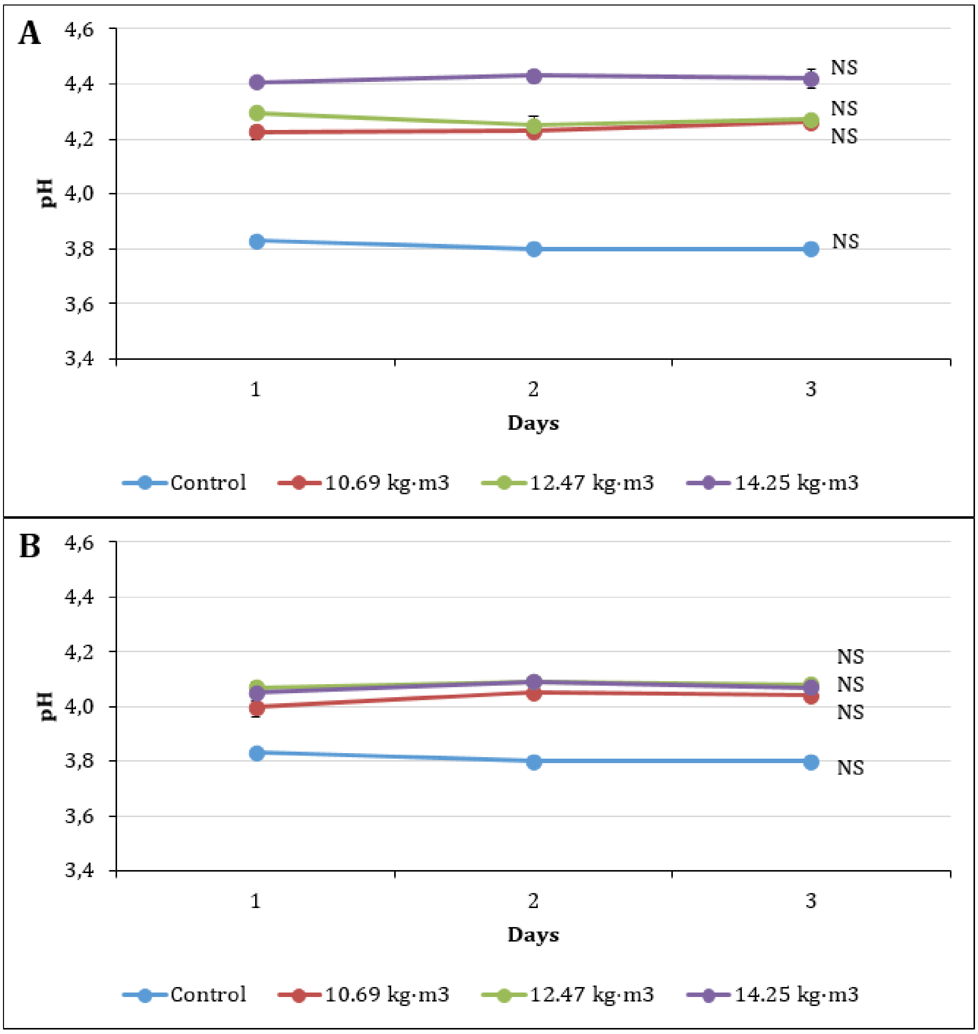

Figure 4. Comparison of pulverized biochars, (A) pine wood (PBC_p) or (B) rice hull (RBC_p), when added to peat moss at three different rates (10.69, 12.47, and 14.25 kg m^{-3}) and compared to 100% peat (control) with no biochar addition to show effects on pH over time. Error bars represent standard error; there were non-significant (NS) effects of each substrate pH over time.

Other tests conducted on these biochars included wettability and pH buffering capacity. When these biochars were mixed into acidic peat, the pH buffering capacity was similar to or less than the pH buffering capacity of peat-perlite substrate (Judd, 2016). Wettability tests on the biochars alone showed both resisted water entering their surface pores, which could affect its ability to neutralize the acidity of peat (Judd, 2016). Due to their characteristics of low pH buffering capacity and hydrophobicity, there seems to be little help for increasing pH directly with the addition of these two biochars.

CONCLUSIONS

In this pulverized form, the two biochars showed little to no effect on neutralizing peat acidity; after seven days from the addition of these pulverized biochars to peat, the maximum substrate pH attained for both was 4.1. The second study increased the amount of pulverized biochar amendments by tripling the low amount (3.56 to 10.69 kg m^{-3}) or doubling the highest amount (7.13 to 14.25 kg m^{-3}). Again, the substrate pH for both pulverized biochars did not reach the recommended minimum for substrates (5.4). While it is clear that biochars made from different feedstocks can produce different benefits and results; the additions of these two pulverized biochars did not provide the quick, short-term effects needed for greenhouse production.

ACKNOWLEDGEMENTS

The authors want to thank all their colleagues and students for their assistance in the biochar production and research for this paper.

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