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Characterization of bonechar as a soil amendment in tropical soils

Abstract

Tropical soils usually lack phosphorus (P) availability due to the high P retention associated with these soils, limiting plant productivity. Brazil is the largest tropical country and worldwide exporter of beef, where overgrazing and frequent slash and burn practices resulted in large areas of degraded pastures. Land degradation and lack of releasable P could potentially be solved using a byproduct of livestock activities– bones– with high P content. The present work evaluates an industrial bonechar (obtained by the pyrolysis of bones) for its potential as a soil amendment. The bonechar's structure and chemical composition were evaluated by using x-ray diffraction, scanning electron microscopy and chemical analyses. The results showed that: i) bonechar is composed mainly of the mineral hydroxyapatite, known to bond with organic molecules of different sizes, which could increase the soil organic carbon stock, and ii) the plant available P in the bonechar is high, 2,800 mg kg^{-1}. Although more studies are needed on bonechar, mainly on its field application, the present work reinforces the production and agricultural use of it as a relevant soil amendment to recover degraded soils in tropical regions.

Keywords: agronomy, agroecology, soil degradation, biochar

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Introduction

Tropical soils, e.g., Oxisols, lack phosphorus (P) availability due to the high P retention associated with clay and mineral content of the soils, limiting plant productivity.[1,2] Some alternatives to increase the soil P and/or its availability, include applying lime, chemical fertilizers, tree litter and manure. In addition, in some natural systems and agroecosystems, P availability can increase over time by ensuring the output of P from the systems (crops, milk, meet, leaching, runoff, etc.) is less than the P input.[3]

Pastoral systems are important for food security and the local economy of many tropical regions, but depending on the adopted management practices they can increase or decrease the soil organic matter[4] that support P availability in these soils. Brazil is the largest tropical country and worldwide exporter of beef, with a cattle stock of more than 200 million animals. Overgrazing and frequent slash and burn practices resulted in large areas of degraded pastures.

Several alternatives have been suggested to recover degraded lands in Brazil, including the adoption of silvopastoral systems.[5,6] Livestock activities result in large quantities of bones; recycling of these bones may have the potential in tropical systems to increase P availability in soils for better plant growth. Approximately 680,000 tons of bones from beef cattle were discarded in 2013. Preliminary experiences in the country adding bones to soil showed its potential benefits as a soil amendment.[7]

There are several advantages in using bones as a soil amendment over other types of P fertilizers. Bones, with a high P content, are available locally and could be a better fertilizer source compared with mineral P that is often expensive for the farmers. Further, reserves of P fertilizers are becoming scarce. Bones are often used in domestic gardens and when pyrolyzed result in a product referred to as bonechar.[8]

Bonechar has some similarities with biochar produced from a variety of other feedstocks (e.g., manure, biosolids, and woody material).[9] Biochar has received great attention in the past decade for its potential to be used as a soil amendment and as a strategy for mitigating climate change.[10] In general, compared to biochar, bonechar has a lower carbon content. In addition, bonechar is free from Cd and U.[11] Studying the effect of bonechar additions on different soil types, Warren et al.[8] concluded that the most important soil properties determining P dissolution of bonechar were a lower pH and higher P sorption, typical characteristics of Oxisols.

In order to develop the potential of bonechar as a soil amendment, the present study evaluated its structure and chemical composition to understand the benefits of adding the material to the plant-soil system. The specific objectives were to describe: i) the chemical properties of an industrial bonechar, and ii) the mineralogy of the bonechar as determined using x-ray diffraction and scanning electron microscopy.

Methodology

The industrial bonechar from *Bonechar Carvão Ativado Ltda*, was characterized by x-ray diffraction and scanning electron microscope at the University of Florida laboratories. The chemical analyses included total P and Mehlich 3 (M3)-extractable K, Ca, Mg, Zn, Si, Na, Mn, Cu, Fe, Al, B, Cd, Ni and Pb. Details of the methodology are available in Freitas et al.[9]

Results and discussion

The bonechar sample characterized by scanning electron microscope shows it is mainly composed of P and Ca (Figure 1A). Figure 1B shows that its structure contains several small pores, which could potentially retain nutrients, organic compounds and water, that are especially relevant for tropical dry regions. The x-ray diffraction showed that bonechar is composed mainly of the mineral hydroxyapatite, a calcium phosphate; the quartz mineral found in the material might be due to contamination of the sample by sand grains. The capacity of the hydroxyapatite mineral to bond with organic molecules of different sizes has attracted attention in the last two decades,[12] a fact that could increase the soil aggregate stability and in consequence the soil organic carbon stock, a key strategy for climate change mitigation and adaptation.

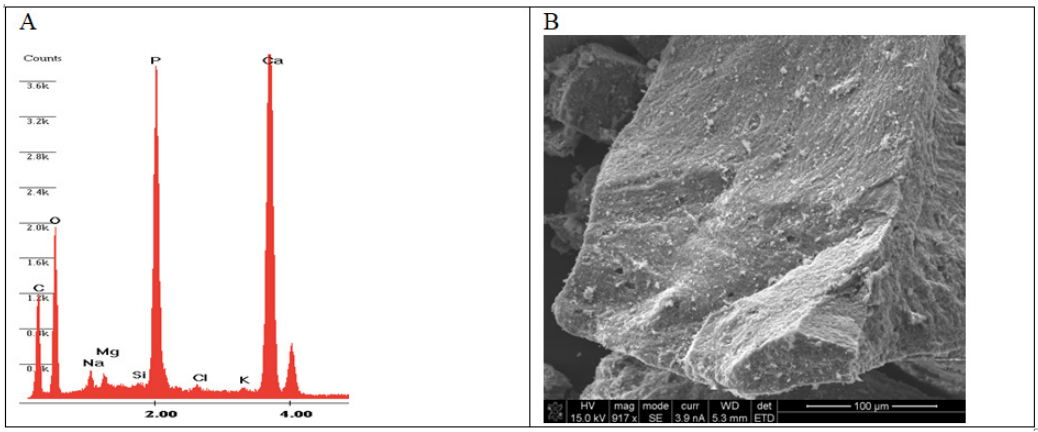

Figure 1 Results of the scanning electron microscope. A) elemental composition of the bonechar; and B) photograph showing pores within the bonechar.

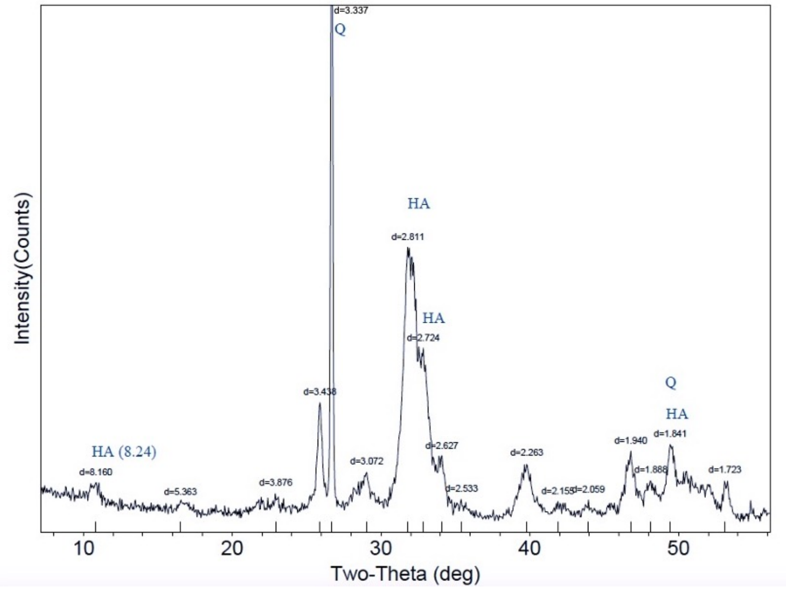

Figure 2 X-ray diffraction pattern of bonechar showing the minerals hydroxyapatite (HA) and quartz (Q).

The chemical analyses also shows that bonechar has P and Ca as the main components (Table 1), in addition to a considerable amount of other essential nutrients (e.g., K and Mg) for plant growth. Components such as Al, Cd, Ni and Pb which could contaminate soils were below the detection limit of the instrument. The high concentration of Na needs to be further evaluated as it could be an issue since its accumulation could result in salt-affected soils. The high Na content might be related to the industrial process that is used to "clean" the bonechar.

Table 1 Total phosphorus, Mehlich 3 extractable- phosphorus (M3-P), potassium (M3-K), calcium (M3-Ca), magnesium (M3-Mg), zinc (M3-Zn), silicon (M3-Si) and sodium (M3-Na) in the bonechar*

	Total P	M3- P	M3-K	M3-Ca	M3-Mg	M3-Zn **	M3-Si	M3-Na
Content mg kg^{1}	124500	2800	1030	6250	1100	5.72	43.4	2800

* Mn, Cu, Fe, Al, B, Cd, Ni and Pb were not included in the table since values were lower than the *Method detection limit* (MDL)

** Value higher than the MDL but lower than *the Practical quantitation limit*

Compared to different types of biochars, bonechar had high total P, while the plant available P (M3-P) in the bonechar, was higher (2,800 mg kg^{-1}) than plant-based biochars with M3-P <480 mg kg^{-1}, although lower than animal-based biochars (>7,000 mg kg^{-1}).[9] The high M3-P concentrations in the bonechar suggests that the material could be a good P fertilizer source. Warren et al.[8] indicated that the bonechar P solubility was intermediate between Gafsa phosphate rock and triple superphosphate fertilizer. Bonechar increased Olsen-P immediately

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after application (1 day) even in soils of relatively high pH in which Gafsa phosphate rock was ineffective.

Conclusion

The present work reinforces the production and agricultural use of bonechar as a relevant soil amendment to recover degraded soils in tropical regions. Further, bonechar applications in forestry (e.g., spot application in planting pits of trees), horticulture, and specialty crops should also be explored seriously. The amount of bonechar added can be adjusted to benefit the plants without harming the environment; the combination of bonechar with compost and manure could be a promising source of amendment and an interesting alternative to inorganic fertilizer. Future farm and laboratory experiments in tropical soils should quantify bonechar's role on the soil P availability, plant growth and soil organic carbon stock. There is an opportunity to compare bonechars from different processing methods, including under homemade conditions. Therefore, bonechar use in tropical soils seems to be a possible solution for making use of waste products of the animal industry to help recover the degraded soils and could go a long way in enhancing crop yields and maintaining soil health.

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Conflicts of interest

Authors declare no conflict of interest.

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