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BIOCHAR: A Potential Mechanism for Achieving Agricultural Benefits

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Introduction

The thermal decomposition of plant-derived biomass (pyrolysis) can be regulated in the partial or entire absence of oxygen to create combustible gases (chiefly H_2, CO, CH_4), volatile oils, tarry fumes, and a solid carbon-rich residue usually referred to as char, in addition to CO_2. Biochar, like char in general, is made up mostly of stable aromatic forms of organic carbon that, unlike carbon from pyrolysis feedstocks, cannot easily be released to the atmosphere as CO_2, even under favorable environmental and biological conditions like those found in the soil.

Biochar is a by product of biomass pyrolysis in a low-oxygen environment. It has a porous carbonaceous structure as well as a diverse set of functional groups (Lehmann and Joseph, 2009). The very porous nature of biochar allows for the extraction of humic-like and fluvic-like compounds (**Lin *et al.*, 2012).** Furthermore, its molecular structure demonstrates good chemical and microbiological stability (**Cheng *et al.*, 2008a**). The physical and chemical properties of biochar are strongly dependent on the feedstock type, as well as pyrolysis temperature and process parameters such as residence time and furnace temperature. (**Joseph *et al.*, 2010; Bruun *et al.*, 2011**).

Biochar has been shown to increase soil microbial qualities as well as chemical and physical properties. Many research have shown that combining biochar with soils can improve soil structure, porosity, bulk density, aggregation, and water retention (**Baiamonte *et al.*, 2015).** Biochar can also increase soil electrical conductivity by 124.6 percent **(Oguntunde *et al.*, 2004)** and cation exchange capacity by 20% (**Laird et al., 2010),** while lowering soil acidity by 31.9 percent **(Laird *et al.*, 2010).** (**Oguntunde *et al.*, 2004**). Furthermore, biochar has been shown to boost soil biological community composition and microbial biomass by 125 percent (**Grossman *et al.*, 2010). (Liang *et al.*, 2010**).

Biochar as a source of nutrients

Available P (0.64 mg kg1), available K (711 mg kg1), available Na (1145 mg kg1), available Ca (5880 mg kg1), and available Mg (1010 mg kg1) were all found in biochar produced from Lantana camara at 300 degrees Celsius (Masto et al., 2013). Fresh biochar, nevertheless, has the potential to increase nutritional availability by releasing considerable amounts of N (23–635 mg kg1) and P (46–1664 mg kg1). As a result, these findings could indicate that biochar has a lot of potential as a source of nutrients. After 24 hours, 15–20 percent of Ca, 10–60 percent of P, and around 2% of N in mallei wood biochar were readily leachable with distilled water, according to Wu et al. (2011). Calculating the long-term nutritional availability of biochars, however, is insufficient. Total N, P, and K in biochar could be utilized as an indirect indicator for selecting optimal biochar in practice.

Factors affecting nutrient content and availability in biochars

` The feedstock source and pyrolytic temperature have a big impact on the nutrient content of biochars (Table 2). In three woody and four herbaceous biochars, for example, N losses began at around 400 °C, and half of the N was lost as volatiles at around 750 °C. Furthermore, when pyrolysis temperatures increased from 350 to 600 °C, the concentration of accessible N (water-soluble) in biochars fell from 39 to 8 mg kg1, which might be attributable to the loss of total N and heterocyclization of N during pyrolysis. The first release of Ca and Mg from maize straw biochar was also pH-dependent, with a rise in the amount released.

The effect of biochar on physical and chemical properties of soils

The physical and chemical features of biochar are important to evaluating its performance and mechanisms in improving soil fertility. The increase in soil water retention capacity after biochar treatment could be one of the key mechanisms for yield improvement. Rice husk biochar elevated the pH of tea garden soil (acid soil) from 3.33 to 3.63, according to research. After biochar application, the levels of extractable nutrient elements (e.g., Na, K, Ca, and Mg) may increase. The amount of extractable K, Ca, Na, and Mg increased by 60 to 670 percent following charcoal addition, according to the findings. Biochar treatment increased base saturation percentage from 6.4 to 26% and saturated hydraulic conductivity from 16.7 to 33.1 cm h1, decreased soil erosion rate from 1458 to 532 g m2 h1, and increased total C from 2.27 to 2.78 percent, total N from 0.24 to 0.25 percent, and available P from 15.7 to 15.8 mg kg1.

Except for organic carbon content and C: N ratios, biochar treatment had no significant impact on soil chemical characteristics. These findings suggested that biochar's effects on soil physical and chemical properties vary depending on the application conditions. Long-term field trials are required to determine whether biochar treatment can permanently alter soil qualities.

Factors influencing function of biochar

The increase in soil pH generated by biochar addition, particularly P and K, is required to improve nutrient availability. Biochar with a high volatile matter concentration, produced at a higher temperature, was found to contribute to N immobilisation and microbial activity reduction, both of which could affect plant growth. Biochar's influence on field capacity and usable water capacity varied across soil types, and these effects were marginally but significantly affected in response to certain soil features, according to the study. Fine-textured soil, which has a higher buffering capacity than coarse-textured soil, was recommended to use a higher amount of biochar (2%) than coarse-textured soil. Furthermore, it was shown that biochar had no effect on maize growth but did improve the growth and nutritional quality of the grass crop that followed.

Application of biochar towards enhancing productivity

1. Enhancing microbial abundance

For the different preincubation times (2–61 days), microbial abundance rose by 5–56 percent as maize stover biochar rates increased (from 0 to 14 percent). Higher availability of nutrients or labile organic matter on biochar surface, less competition, improved habitat suitability and refuge, greater water retention and aeration, or positive priming are all plausible reasons for the rise in microbial population.

2. **Availability of elements in soil**

Biochar has the potential to store up to 12% of anthropogenic greenhouse gases (CO_2, CH_4, and N_2O) in ecologically and economically sustainable systems. The use of biochar in agricultural soils has been found to prevent nitrogen leaching.

3. **Nutrition and fertility of soil**

Biochar has the potential to prevent pollutant leaching in agricultural soils. The impact of biochar on plant growth is mostly determined by characteristics such as biochar type, dose rate, mixing depth, nutrient availability, plant species, and soil texture. (O'Connor *et al*., 2018; G. Zhang *et al.*, 2017)

4. **Heavy metal contaminates in soil**

Since the porous structure and wide surface area of ageing biochar, as well as the enhanced CEC of ageing biochar, it has been deemed an environmentally and economically feasible solution for remediating heavy metal-contaminated soils with its outstanding efficacy and adaptability.

5. **Remediation of non-agricultural soils**

Soil salinization and sodification are two primary risks to soil production in arable fields that occur frequently. The use of biochar to improve the physical, chemical, and biological aspects of salt-affected soils was found to be successful.

Conclusion

Biochar should be made with care, with the feedstocks chosen properly and the preparation conditions adjusted according to the intended use. Biochar made from biomass, manure, or other wastes had a lot of potential for soil development, and it also showed that biochar could be used to treat saline-alkali or industrial soils, which had a lot of advantages. However, both biochar and soil behaviour during long-term soil rehabilitation should be thoroughly investigated. Multiple issues, such as socioeconomic limits, environmental and public health dangers, and a lack of customer recognition, must also be addressed. In conclusion, more research into technology or policy is needed to discover the best preparation and popularisation methods for biochar, and the acceptability and sustainability of biochar as a soil remediation tool is gaining traction.

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