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Biochar and Sustainable Agriculture

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Abstract

Synthetic fertilizer uses out of balance results in a decline in the production and health of the soil. Chemical fertilizers may initially have a good impact, but their continued use alone has negative consequences on the health of the soil. Utilizing biochar effectively may make it possible to control soil health and encourage fertility. Millions of tons of biomass and crop waste that aren't used as animal feed might be converted into biochar in India and used to boost the carbon content of the soil. The high surface area, CEC, high water-holding capacity, pore size; volume and distribution, as well as molecular structure of biochar, among other chemical, physical, and biological characteristics, can increase nutrient availability and microbial communities for enhancing soil. To appropriately gauge the sustainability of using biochar in agriculture to capture carbon and restore soil function, rigorous research examining the long-term effects of the substance on soil characteristics are still required.

Keywords: Biochar, pyrolysis, sustainability, carbon

Introduction:

The present research interest in biochar for carbon sequestration is growing as political and scientific awareness of climate change and issues with residue burning increases. India produces 500 MT of crop wastes per year, of which 141 MT are surplus. Due to various restrictions, these residues are either completely unutilized or only partially used. When left untreated, surplus and unneeded agricultural leftovers frequently disturb field preparation, crop establishment, and early crop growth. As a result, they are typically burned on farms, which release air pollutants, including greenhouse gases (GHG), and results in significant nutrient losses. The conversion of crop wastes and other useless biomass into biochar through a thermo-chemical process (slow pyrolysis) is becoming more and more important as a cutting-edge and financially viable alternative method of managing surplus and unusable crop residues and biomass. The surplus residues present in India can be converted into a beneficial material for boosting soil health and crop productivity by converting crop residues and on-site agro-forestry residues to biochar and applying it to the soil as a soil amendment. The creation of biochar and its application to soil could be advantageous and provide benefits beyond carbon sequestration. This entails enhancing the physical qualities of soil that are advantageous to crops, enhancing the retention and availability of soil nutrients, enhancing biological activity and resulting in higher crop yields, as well as societal benefits through the reduction of non-CO2-greenhouse gas emissions and the mitigation of global warming through carbon sequestration.

What is Biochar?

When plant biomass is subjected to the thermo-chemical conversion process (pyrolysis) at low temperatures (350-600°C) in an atmosphere with little to no oxygen, the result is a fine-grained, carbon-rich, porous substance known as biochar. In contrast to pure carbon, biochar is a mixture of various amounts of carbon (C), hydrogen (H), oxygen (O), nitrogen (N), sulphur (S), and ash. Biochar is included in the category of substances known as "charcoal" or "black carbon," while black carbon made from fossil fuels or non-biomass trash is not. It's very porous structure, which may be to blame for improved water retention and increased soil surface area, is the essential characteristic of biochar and char that makes it significant as a soil amendment.

Production of Biochar:

A variety of high-molecular lingo-cellulosic materials can be used to make biochar. To create biochar, a variety of heat conversion techniques can be applied. The four types of pyrolysis systems used to convert unneeded and surplus crop and agroforestry residues for the creation of biochar are slow pyrolysis, fast pyrolysis, flash pyrolysis, and gasification. A significant output of biochar (35%), produced via slow pyrolysis carried out at lower temperatures (400–500°C) and with lengthy contact durations, is common. Faster gasification or pyrolysis operates at higher temperatures (800°C) and produces a high yield of combustible gases in comparison to the solid charcoal (12%). The process of slow pyrolysis is the one used the most frequently to produce biochar. Under oxygen-deprived circumstances in a closed reactor, this technique uses direct thermo-chemical decomposition (exothermic reaction) to convert low-density residue matrix into biochar. Three steps make up the process in commercial biochar pyrolysis systems: first, moisture and some volatiles are removed; second, un-reacted wastes are transformed into volatiles, gases, and biochar; and third, the biochar undergoes a gradual chemical rearrangement (Demirbas, 2004).

Effect of Biochar on soil physical & chemical properties:

The application of biochar may help degraded soils' physicochemical characteristics. Biochar can hold onto soil water because of its surface functioning and porous interior structure. Several researches revealed that applying biochar can enhance total pore volume, decrease bulk density of soil, and improve water retention capacity (Abel et al., 2013; Chan et al., 2007).

Effect of Biochar on Soil Biological Properties:

The cycling of nutrients is greatly aided by the vital ecosystem service that soil microorganisms perform. When compared to the addition of fresh organic matter, applying biochar to soil has various impacts on the soil biota, which may have an impact on the diversity, activity, and abundance of biotic communities in the soil. Instead of giving microorganisms a primary source of nutrients, biochar is expected to alter the physical and chemical conditions of soils to create a more appropriate home for them (Lehmann et al., 2011). Still little is known about the precise impacts of biochar on the microbial population in soil.

Biochar and heavy metal contamination:

For the treatment of soils contaminated with heavy metals, biochar is a possible choice. The concentration of soil contaminants, physicochemical properties, and the stability of the metal-biochar complex, which may be correlated with the type of pyrolysis process, all influence how contaminants and metals are retained and released. The primary mechanisms that are typically taken into consideration for how biochar adheres to heavy metal pollution are as follows: 1. Ion exchange 2. Coprecipitation 3. Complexation 4. Electrostatic absorption (Wang et al. 2018).

Biochar and Carbon Sequestration:

By using photosynthesis to create organic matter, atmospheric CO_2 is removed from the atmosphere and eventually stored in the soil as long-lasting, stable forms of carbon. Terrestrial, atmospheric, oceanic, and geological systems are significant sources of C. Rapid movement of carbon between pools occurs in the active C pool (Lehmann, 2006). Moving C into a passive pool with stable or inert C is important to minimize the amount of C in the atmosphere. C may easily flow from the active pool to the passive pool with the help of biochar. Controlled carbonization, as opposed to burning, produces stable C pools from even greater amounts of organic biomass, which are thought to last for generations (Glaser et al., 2001). In contrast to the little amounts retained after burning (3%) and biological degradation (less than 10- 20% after 5–10 years), the conversion of biomass carbon to biochar results in the sequestration of roughly 50% of the initial carbon (Lehmann et al., 2006). The kind of feedstock has a considerable impact on how effectively biomass is converted to biochar, whereas the pyrolysis temperature (which is typically between 350 and 500 °C) has little impact.

Effect of biochar application on crop yield and quality

It has been demonstrated that adding biochar to the soil increases agricultural output and quality, either directly or indirectly. By serving as a source of nutrients, it immediately aids in the growth of the plant. The favorable impact of biochar on the physical, chemical, and biological characteristics of soil may help to explain the indirect effect.

Conclusion:

In addition to being an excellent source of carbon, biochar also possesses a number of qualities that can enhance soil health and boost agricultural productivity. Significant environmental and agricultural benefits may be attained if agricultural biomass wastes, which are currently burned in India and other countries, were pyrolyzed into biochar's and used to enrich the soil. First, producing biochar would produce less CO_2 than burning trash and waste outdoors. As a result, rather than just being ash from open burning, a greater portion of the carbon in these wastes would be returned to the soil as biochar. All of the essential micronutrients that are lacking in many agricultural soils are found in biochar, which could provide them in a form that is less likely to be fixed in soil. Since a sizeable portion of the carbon in biochar does not decompose, it remains trapped in the soil for extended periods of time, preventing global warming and fostering microbial activity. So that open burning of biomass and the ensuing issues of air pollution, global warming, and decline in soil quality could be significantly reduced without sacrificing the sustainability of food production, these advantages need to be established by long-term field trials for various cropping patterns.

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