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Biochar: A Promising Technology for Sustainable Soil Health and Climate Change Mitigation

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ABSTRACT

The main threats of the 21st century are land degradation and climate change, which harm crops as well as animals. Biochar application to soil has been widely advocated as an approach to enhancing soil health and reducing climate change. Biochar also acts as a sink for atmospheric CO_2 in the soil due to its unique characteristics. Biochar also offers a lot of environmental solutions to minimize greenhouse gases emissions. Therefore, by converting agricultural and other waste into a potent soil supplement is a promising method for improving soil health and minimizing climate change effects, as well as for increasing food and feed security, preventing deforestation, and lowering fertilizer needs.

INTRODUCTION

Climate change and food-fodder insecurity are two key issues globally nowadays. To fulfil ever increasing nutritional food-fodder demands of the expanding human and livestock populations and make sustainable agriculture, improvement in soil health is indisputable. However, soils from various agricultural systems suffer a number of challenges, including soil erosion, soil carbon depletion, nutrient imbalance, and loss of soil biodiversity (Rasoulzadeh 2019). Sustainability in food-fodder system and climate change mitigation can be achieved by sequestering atmospheric CO_2-C in agricultural soils. Continuous soil organic carbon (SOC) depletion due to unhealthy farming practices and high crop intensity decreases resource use efficiency and crop productivity. Therefore, maintaining high levels of SOC through the continuous application of organic materials is much required for improving soil quality, sustaining agricultural productivity, and reducing greenhouse gases (GHGs) emission. Therefore, there is an urgent need to have more practical and economically friendly practices that supports long-term sustainable soil health and productivity. One strategy that is attracting a lot of interest is the utilization of biochar as an amendment to enhance environmental sustainability and soil health (Choudhary 2023).

A low density, carbon-rich, porous substance known as biochar is created by pyrolyzing organic biomass in an O_2 limited or free condition (Lehmann and Joseph 2015). Historically, biomass derived char was used in the central Amazon basin as a soil amendment for at least 2000 years. According to Guo (2016), the "Terra Preta" (Portuguese for "dark earth") soils that have had recurrent biochar amendments have been more productive than the Oxisols and Ultisols that they are situated near. The finding suggests that biochar is a useful supplement for consistently improving and maintaining soil health, fertility, and production, as well as for cleaning up sites that have been contaminated by metals and lowering greenhouse gas emissions (Awad 2018). When biochar is added to soil, its physiochemical properties, in particular, raise the pH, CEC, surface adsorption capacity, base saturation, and disease resistance of crops. (Anawar 2015). Soil bulk density and water-holding capacity are impacted by the application of biochar. (Santos and Pires 2018). Additionally, it also affects the various physic-chemical attributes of soil (Veni 2017; Choudhary 2022). According to Zhu (2017) and Pandit (2019), biochar is also effective to enhancing population of microbes in low fertile soils and improving the soil fertility. Numerous studies have shown that adding biochar to plants influences growth metrics such as germination rate, shoot and root growth, and plant survival (Wang 2019; Teodoro 2020). The effects of applying biochar on build-up of SOC, soil characteristics, and productivity in several experiments depending on the composition of biochar, types of soil and climatic conditions. Some studies believe that the water-holding capacity, ash content, pH, specific surface area, bulk density, volatile chemical content and pore volume features can be utilized to evaluate biochar (Sohi 2010).

PROCESS OF BIOCHAR PRODUCTION

Biochar can be made using a variety of heat conversion techniques. Four types of pyrolysis systems are used to convert leftover and surplus crop and agroforestry residues for the biochar production:

1. Pyrolysis
2. Gasification
3. Torrefaction
4. Flash carbonization

PREPARATION OF BIOCHAR

There are many means to make biochar, but typically it involves heating biomass in the absence of oxygen to release volatile gases and retain carbon. Biochar can be prepared on a scale varying from massive industrial plants to a small farm, making it useful in a variety of socioeconomic settings. For biochar technology to become widely accepted among stakeholders, it is crucial to create a cheaper biochar kiln at the neighborhood level or a cheaper biochar stove for each farmer's home. The following are some of the trendy techniques:

1. Heap Method
2. Drum method
3. Standard biochar production unit

BIOCHAR EFFECTS ON SOIL HEALTH

Biochar as a soil amendment can change properties of soil at different levels of physical, chemical and biological status.

1. It has been established that biochar has the capacity to increase availability and retention of nutrients, which improves soil fertility.
2. The high porosity of biochar enhances soil water retention. It absorbs water and gradually releases it, much like a sponge, reducing runoff and increasing soil moisture. In arid and semi-arid regions, this capability is extremely useful. Numerous studies have found that applying biochar significantly improves soil water retention.
3. It has been reported that biochar has positive effects on activity and population of soil microbes. Mycorrhizal bacteria and fungi, which plays important role for the nutrient cycling, the prevention of diseases, and the boost of plant growth, can live there. It also provides a home for other helpful microorganisms. By supplying a consistent carbon source and improving soil aeration, biochar can improve activity and diversity of microbes.
4. Applying biochar can boost SOC stock by increasing the quantity of organic carbon present.
5. Applying biochar to the soil improves soil stability and structure, which lowers soil erosion via improved soil aggregation. To sustain fertility of soil and agricultural yield, surface soil retention is essential, and biochar makes that possible.

6. Biochar is necessary to preserve nutrients in the soil and make them accessible. Its substantial surface area and porous nature allow it to capture soil nutrients, reducing leaching losses, thus, improving nutrient availability to crops.
7. Biochar aids in drainage control and soil water retention. Its porous structure helps to improve its capacity to retain water and to drain it.
8. It has been demonstrated that biochar can control the pH of soil.
9. Due to its unique characteristics, biochar is crucial in pollutant removal through adsorption, ion exchange and chemical reactions.
10. Biochar can significantly improve water quality through a variety of procedures.

BIOCHAR FOR CLIMATE CHANGE MITIGATION

Long-term carbon retention in soils is possible using biochar. Biochar incorporation in soils offers a wide range of other possible climate advantages, apart from being a source of carbon.

1. Carbon sequestration: One of biochar's significant environmental benefits is its ability to permanently carbon sequestration in the soil for long -term, reducing climate change impacts by lowering greenhouse gas emissions.
2. N_2O oxidizes a variety of aromatic and aliphatic molecules, which includes the bioavailable C in charcoal. The internal and external surfaces of biochar are covered in a variety of aromatic and non-aromatic chemicals, which reduce N_2O.
3. Biochar can lower agricultural soil emissions of greenhouse gases viz. N_2O and CH_4.
4. Biochar can boost soil microbial activity, which increases soil's capacity to store carbon.
5. By turning crop residues and other waste materials into biochar, greenhouse gas emissions that would have been produced by the material's burning or natural decomposition can be avoided.
6. Biochar can lessen the requirement for chemical fertilizers, which reduces greenhouse gas emissions from fertilizer production.

CONCLUSION

In summary, One workable solution to increase soil's capacity to naturally store carbon, cut down on farm waste, and improve soil health is the utilize biochar in agro ecosystems. By adding biochar to the soil, it is possible to reduce the release of greenhouse gases such as CH_4, CO_2, and N_2O into the environment. Apart from that, biochar also improve various soil properties. To further understand the biochar's long-term consequences on availability of nutrient, activity of microbes, carbon storage, productivity, and reduction of greenhouse gases, multidisciplinary and site-specific research must be undertaken.

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