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Effect of Biochar on Physical and Chemical Properties of Soil

Kancharla Ashok Kumar[1], Dumpapenchala Vijayreddy[2] and Lakkam Yashwanth Reddy[3]
[1]Department of Plantation, Spices, Medicinal and Aromatic crops, College of Horticulture, Rajendranagar, Sri Konda Laxman Telangana State Horticultural University, Mulugu, Telangana, India - 502279

[2]Ph. D. Scholar, Department of Plant Pathology, Division of Crop Protection, Indian Agricultural Research Institute (New Delhi), Indian Institute of Horticultural Research, Hessaraghatta, Bengaluru, Karnataka, India – 560089

[2]Ph. D. Scholar, Division of Germplasm Conservation and Utilization, ICAR-National Bureau of Agricultural Insect Resources (NBAIR), Post Bag No. 2491, H.A. Farm Post, Bellary Road, Bengaluru, Karnataka, India – 560024

[3]PG Scholar, Department of Vegetable Science, College of Horticulture, Rajendranagar, Sri Konda Laxman Telangana State Horticultural University, Mulugu, Telangana, India – 502279

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Abstract

Healthy soil is the foundation of sustainable agriculture. Acidic soil is a big issue in many places of the world, including India. Biochar, a charcoal-like substance made by burning organic debris, is a possible alternative. Biochar has several advantages. Its porous structure behaves like a sponge, retaining more water in dry soils. This expanded surface area also facilitates nutrient adsorption, making nutrients more accessible to plants. In addition, biochar can help neutralise acidic soil, making it more conducive to plant development. The efficiency of biochar is determined by how it is manufactured. Its qualities are influenced by the temperature at which it is manufactured and the type of organic material utilised. Research is being conducted to optimise production methods for certain soil types. Biochar has enormous potential for increasing soil fertility and encouraging sustainable agriculture practices. Its capacity to increase water retention, nutrient availability and neutralise acidity makes it an important tool for farmers looking to boost crop yields and soil health.

Keywords: Biochar, Nutrients, Organic matter, Problematic soils, Sustainable agriculture

Introduction

Soil is the basic foundation of sustainable crop production and the soil quality impacts crop production. Out of 142 million ha of cultivable land in India, 49 million ha of land is acidic, of which 26 million ha of land has a soil pH less than 5.5 and the rest 23 million ha has a soil pH range of 5.6 to 6.5.

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To overcome the problem of soil acidity, farmers adopt a variety of soil amendments like manures, lime, compost and bio-sorbents to make soil nutrients available to crops besides protecting them from toxic elements. Among soil amendments, liming is a good practice to overcome the acidity problem. Even so, it may not be economical in the regions where it is expensive. The alternate cheap and good organic source to overcome the acidity problem is biochar (Chan *et al*., 2008).

Biochar is a solid carbonaceous material obtained from thermally degrading biomass in the presence of little or no oxygen. It is ordinarily defined as scorched organic matter, intended to be applied to soils to sequester carbon and improve soil properties. In more technical terms, biochar is produced by thermal decomposition of organic material under limited supply of oxygen known as pyrolysis. Adding biochar to soils has been proved to improve soil physical, chemical and biological properties along with climate change mitigation. It is reported that conversion of biomass into biochar not only results in renewable energy, but also decreases the concentration of CO_2 in the atmosphere, which emphasises more research on the effect and behaviour of biochar in the soil (Reddy and Vijayreddy, 2023). Biochar offers an opportunity for carbon sequestration, soil restoration, renewable energy production and waste utilization. The global annual production of black carbon (biochar) has been estimated to be between 50 and 270 T g yr^{-1}, with as much as 80 per cent of this remaining as residues in the soil. Biochar is not a pure carbon, but rather a mix of carbon (C), Hydrogen (H), Oxygen (O), Nitrogen (N), Sulphur(S) and ash in different proportions. The central quality of biochar that makes it attractive as a soil amendment is its highly porous structure potentially responsible for its improved water retention and increased soil surface area. The biochar enriched with organic and inorganic materials can have better results on soil properties and crop production as there will be an extra addition of nutrients from enriching materials. The biochar can be applied to acid and alkaline soils as it plays an important role as a soil conditioner and buffer which can increase or decrease the pH of the soil. The addition of biochar to the soil was found to reduce leaching losses of nitrogen and phosphorous and also acts as soil conditioner in decreasing the bio-availability of contaminants in soil.

Maximum heating temperature and heating rate have a strong influence on the retention of nutrients as does the original composition of the feedstock. The stability of biochar critically depends on the production procedure. greater stability of charcoal produced at 400 ^{0}C than 1000 ^{0}C. The effect of temperature has led to suggestions that biochar created at low temperatures may be suitable for controlling the release of fertilizer nutrients, while high temperatures would lead to a material analogous to activated carbon (Ogawa *et al*., 2006). Unlike the carbon found in most organic matter biochar carbon was chemically altered during the heating process and formed into benzene-type ring structure that is very resistant to attack by microorganisms (Vijayreddy, 2024). The adsorption capacity of biochar is an important factor in determining how biochar will

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perform. The strong resistance of biochar to microbial decomposition and hence its continued persistence in the soil ensure that the benefits of biochar application would be long-term. Rajapaksha *et al*. (2014), reported that biochar had been applied to improve soil quality, enhance C sequestration and immobilize contaminants.

Effect of biochar on soil physical properties

Application of biochar, increased soil organic matter, water holding capacity, bio-available nutrients and significantly enhanced the microbial activities (Vijayreddy, 2024) and thereby the soil aggregate formation and stability. Biochar increased the available water capacity by 97 per cent, saturated water content by 56 per cent and reduced hydraulic conductivity with increasing moisture content when compared to un-amended soil. In addition to improvement in surface area, porosity and soil aeration were also improved upon biochar application (Sean *et al*., 2012). Andres *et al*. (2013) revealed that the addition of biochar decreased the gravity-drained water content by 23 per cent relative to the control. The bulk density of the control soils increased with incubation time (from 1.41 to 1.45 g cm^{-3}), whereas the bulk density of biochar-treated soils was up to 9 per cent less than the control and remained constant throughout the incubation period.

The physical properties of biochar such as large surface area and presence of micropores contribute to the adsorptive properties of biochar and potentially alter soil's surface area, pore size distribution, bulk density, water holding capacity and penetration resistance (Mukherjee and Lal, 2013)

Effect of biochar on soil chemical properties

Biochar produced at higher pyrolysis temperatures increases soil pH more than biochar produced at lower pyrolysis temperatures at the same application rate. Also, steam activation increased the liming capacity of biochar (Hass *et al*., 2012). The incorporation of biochar produced from crop straws increased the soil pH, exchangeable base cation, CEC and base saturation and decreased exchangeable acidity, exchangeable Al and reactive Al. The resultant effects were dependent upon feedstock characteristics and pyrolysis temperature (Wan *et al*., 2014). The application of alkaline biochar did not increase the soil pH but instead decreased pH, especially with higher rates of application. Acidic materials produced by the oxidation of biochar and organic matter decreased the pH. The high soil cation exchange capacity caused by the biochar application might restrict the soil salinization process to some extent (Liu and Zhang (2012)). The effectiveness of biochar in ameliorating acidity which increased the soil pH, EC and CEC and decreased the exchangeable acidity. The liming potential of biochar can be attributed to their alkalinity, proton consumption capacity and base cation concentration (Chintala *et al*., 2014).

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Conclusion

Soil is essential for sustained crop production, and its quality has a substantial influence on agricultural output. Acidity affects a large amount of India's cultivable land, causing issues for farmers. Soil additives such as manures, lime, compost, and biosorbents are utilised, however, their economic viability is questioned. Biochar, generated from the thermal breakdown of biomass, can enhance soil characteristics and decrease acidity. The porous construction increases water retention, soil surface area, and nutrient availability. Biochar's ability to withstand microbial degradation assures long-term advantages. According to studies, it can improve soil pH, organic matter, and water retention capacity. However, the manufacturing method and features of biochar, such as temperature and feedstock content, have a considerable impact on its efficacy. Further study is needed to optimise and maximise biochar production.

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