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EDITORIAL

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Biochar as a Versatile and Beneficial Soil Amendment: Recent Approaches

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Biochar is a promising and viable fertilizer carrier for microbial fertilizers due to its porosity (Wang et al., 2023). Biochar is a type of charcoal produced in the slow pyrolysis of organic materials, such as agricultural waste (Aziz et al., 2023). Pyrolysis, the method used to create biochar, is the conversion of organic materials into a stable form of carbon that can survive in soil for a very long time (hundreds to thousands of years). Recently, a co-pyrolysis technique for improving sewage sludge biochar's performance and immobilizing heavy metals was presented (Fan et al., 2023; He et al., 2023). When organic matter is heated in the absence of oxygen, it can break down into its constituent components without catching fire, resulting in the development of biochar. In order to create biochar, which may be used as a soil amendment to enhance soil health and fertility, a variety of organic waste products, including agricultural waste, forestry residue, and sewage sludge, are employed in the production process. Contrary to conventional charcoal, which is largely used as fuel, biochar is applied to soil as a soil supplement to increase soil fertility and production (Khedulkar et al., 2023). This enables it to absorb carbon from the air, lowering the concentration of greenhouse gases and lessening the effects of climate change.

Agriculture and biofertilizers are related from a long time (Kaushal and Singh, 2022; Kumar, 2022; Jasim et al., 2022; Goyal et al., 2023). Charcoal was also utilized to increase soil fertility by the ancient Greeks and Romans. The use of biochar has grown in favour recently as a strategy for lessening the effects of climate change, enhancing soil health, and lowering the need for synthetic fertilizers and other inputs. When applied to soil, biochar has various positive effects. First and foremost, it can enhance soil fertility and structure, which can result in increased crop production and better plant health. Additionally, biochar has the capacity to hold onto moisture and nutrients in the soil, extending the time that they are available to plants. As a result, less fertilizer and irrigation may be required, lowering the cost of agricultural production.

In addition to its advantages for the soil and crops, biochar can lessen the release of greenhouse gases from the soil, including carbon dioxide and methane. According to a recent study, differing gasification biochar grain sizes have an impact on how much ammonia and greenhouse gases are released during municipal aerated composting procedures (Ottani et al., 2023). This is so that biochar may sequester carbon and lower the quantity of greenhouse gases in the atmosphere. Biochar's carbon is very resistant to degradation, so it can stay in the soil for a very long time. The creation of biochar is also advantageous for the environment since it may lessen the quantity of garbage that would otherwise be burnt or dumped in landfills. Biochar can assist in lowering the carbon footprint of forestry and agricultural activities by transforming this waste into a beneficial soil supplement.

Despite all of its advantages, making and using biochar still presents certain difficulties. The absence of uniform standards for biochar production is one of the key issues. Additionally, it can be energy-intensive to produce biochar, and the high temperatures needed for the job can cause airborne pollution.

Biochar holds the potential to increase the sustainability and environmental friendliness of agriculture by enhancing soil health and lowering the need of synthetic inputs. The present review highlights the advantages and applications of biochar associated with various fields of agriculture and environmental health. Recent research on biochar has explored its potential for a range of applications, from soil improvement to greenhouse gas mitigation (Banik et al., 2023; Canatoy et al., 2023; Xiong et al., 2023; Zhou et al., 2023).

Biochar and soil fertility

The use of biochar as a soil additive to increase soil fertility is one of its main uses. According to researches, by applying biochar to the soil enhances the agricultural production and soil fertility. It has been demonstrated that maize biochar has a significant influence on the functional group networking and composition of the rhizosphere microbial community, notably fungus, leading to an increase in soil fertility (Liu et al., 2022).

In another study, sewage wastewater (SWW), control fresh water (CFW), rice husk biochar (RHB), NPK fertilizer and NPK + RHB treatments were arranged with four replications. Reapplying RHB exhibited a little capacity for retaining C and N in soil aggregates, but when combined with NPK, it generated a greater response in terms of soil nutrient retention, soil structural stability, and TC and TN sequestration potential in micro- and macro-aggregate fractions. Therefore, NPK + RHB treatment was found best for the sustainable management of soil (Okebalama and Marschner, 2023). As a result, crop yields may increase and less synthetic fertilizer and pesticide use may be required.

Biochar and greenhouse gas mitigation

In addition to improving soil fertility, biochar may also help reduce greenhouse gas emissions, according to various studies. It boosts the soil fertility through enhancing soil structure and nutrient availability. In a recent research, the ammonia and greenhouse gas emissions from the co-composting of the organic component of municipal solid waste were examined as a result of the application of minimal quantities of two different sized biochars produced by biomass gasification. It was discovered that independent of the biochar particle size, fine and coarse gasification-derived biochars enhanced the bio-oxidative phenomena and decreased greenhouse gas emissions of the composters (Ottani et al., 2023). In another recent study, the researchers stressed that further research is required to better understand nitrogen primary transformation rates and the proportional contributions of CH_4 generation, and that 1% should be a more realistic biochar addition ratio for reducing greenhouse gas emissions in sandy loam soils (Zhou et al., 2023).

Biochar and water retention

Making improvements to the water-holding characteristics and water-erosion resistance of desert soils, particularly in inland extremely arid areas, is vital for achieving both sustainable water resource utilisation and food security. Adding biochar to soil may increase water retention and decrease evaporation-related water loss. A study reported that 0.08 g/kg of carboxymethyl cellulose sodium (CMC) and 8.0 g/kg of biochar were used as recommended for improving the hydraulic properties of desert soils. Generally speaking, CMC and biochar have complementing effects on enhancing sandy desert soil, offering fresh perspectives and methods for enhancing soil and fostering the sustainable growth of agriculture in desert regions (Shao et al., 2023).

Biochar and heavy metal uptake

Applying cost- and environmentally- conscious technology in line with the idea of green, sustainable development is essential for successful soil restoration. In the context of recycling waste and preserving nutrients in the soil, biochar production and utilization have become widespread. It has been demonstrated that biochar can decrease the absorption of heavy metals by crops. A study looked at the effectiveness of employing biochar generated from three different sources including wood and agricultural wastes (sunflower and rice husks), to remediate soil. In this experiment, all biochars functioned well as an absorbent for removing heavy metals from soils. The tailor-made surface chemistry properties and the high sorption efficiency of the biochar from sunflower and rice husks could potentially be used for soil remediation (Burachevskaya et al., 2023). A number of recent researches have analyzed the significance of biochar for removing the heavy metals (Fan et al., 2023; He et al., 2023; Huang et al., 2023; Lin et al., 2023; Manikandan et al., 2023).

Soil carbon sequestration

The capacity of biochar to trap carbon in soil is another important benefit. Biochar is a powerful instrument for carbon sequestration since the carbon in it is extremely stable and resistant to deterioration. By decreasing the quantity of carbon dioxide (CO_2) in the atmosphere and so lessening the consequences of climate change, biochar can raise soil carbon levels. This is especially important for agriculture because it contributes significantly to the world's greenhouse gas emissions. Farmers may significantly reduce the consequences of climate change by utilizing biochar as a soil amendment. A research discovered that co-pyrolysis increased the carbon sequestration capability of biochar, which was linked to the natural minerals in sewage sludge from populated areas (He et al., 2023).

Plant growth promotion

Biochar increases agricultural yields and encourages plant development. Biochar amendment provides multiple benefits in enhancing crop productivity. Biochar's high CEC can increase the availability of nutrients in the soil, which will boost plant development and increase agricultural yields. Additionally, the biochar's porous structure can enhance soil aeration and water penetration, supporting strong root development and enhancing plant water usage efficiency. These advantages can assist farmers in increasing yields and raising their general productivity. A study presented a digestate-encapsulated biochar derived from food waste, had the best effectiveness as seen by 9-25% increase in chlorophyll content index, fresh weight, leaf area and blossom frequency (Yan et al., 2023). Another study reported an enhanced plant total N, P, K, Ca uptake, and biomass upon biochar application (Wan et al., 2023).

Environmental remediation

The impact of various contaminants on ecosystem components, as well as their known or suspected ecotoxicity and detrimental health impacts, make their presence a critical problem. Biochar has been shown to have a number of environmental benefits, including the remediation of contaminated soils. Biochar has been shown to have a high adsorption capacity for a wide range of contaminants, including heavy metals, organic pollutants, and other toxins (Ahmad et al., 2023). This makes biochar an effective tool for remediation of contaminated soils, helping to reduce the risk of environmental pollution and improve the health of ecosystems (Ajala et al., 2023).

Conclusion

Biochar is a promising fertilizer carrier. Current biochar research has looked at its potential for a variety of uses, such as soil enhancement and greenhouse gas mitigation. This review reveals how biochar has the ability to increase soil fertility and production, lower greenhouse gas emissions, increase water retention, and decrease the absorption of heavy metals by plants. These results indicate that biochar has significant promise as a technique for enhancing soil health and minimizing the negative environmental effects of agriculture. However, further studies are required to completely comprehend the advantages and difficulties of using biochar as well as to establish guidelines for its manufacture and application.

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