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Biochar For Sustainable Improvement of Soil Health

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Introduction:

The primary objective of modern and emerging agriculture revolves around the provision of both safe and nutritional food to the expanding global population. But, its consequences on soil health and agricultural production have become more significant in the regard of global climate change. To address such concerns, biochar is a promising option with several beneficial properties, such as high porosity and surface area, the carbon sequestration ability, reduce nutrient leaching and soil acidity; and a role in mitigating climate change. Biochar is a charcoal-like substances produced by the process of pyrolysis in a limited-oxygen condition at temperatures between 300 and 1,000°C using organic biomass as a feedstock. Biochar contains macronutrients such as nitrogen, phosphorus, and potassium along with its primary elements (carbon, hydrogen, and oxygen). Depends on feedstock and production process, the overall composition and characteristics of biochar changes. The soil application of biochar has been reported to enhance soil structure, boost nutrient retention, foster the growth of microorganisms, and increase plant nutrient uptake. Biochar also acts as a source of pollutants such as heavy metals, volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons (PAHs), and dissolved organic carbon, depending on the composition of biochar.

Properties of biochar:

The state of feedstock and the process of pyrolysis affect the biochar production, which differ in physical and chemical properties. Biochar produced from wood with high lignin content has higher carbon contents than herbaceous feedstocks. Due to heterogeneous properties, the biochar composition has both unstable and stable components. The important constituents of biochar for characterization are surface area, carbon content and mineral matter (ash).

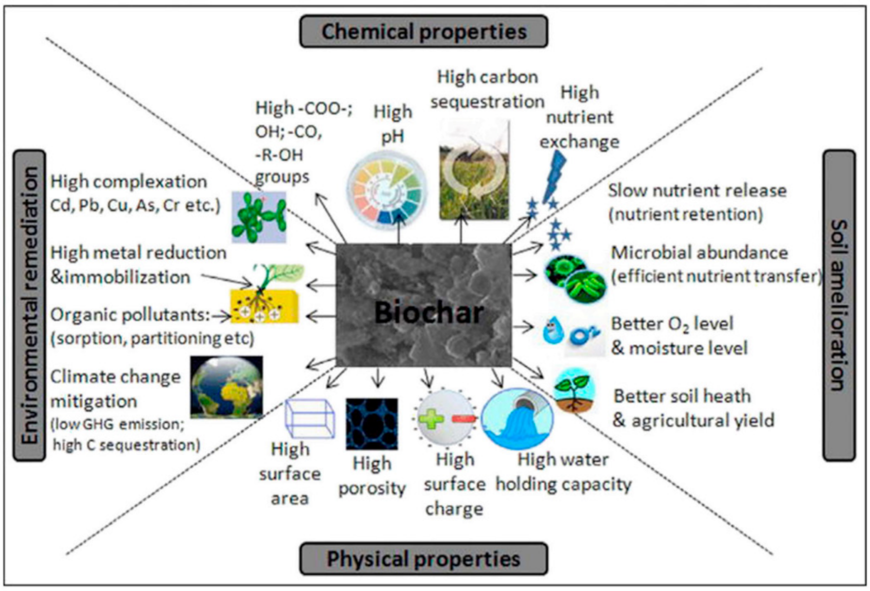

Fig.1 Physicochemical properties of biochar

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Production of biochar

Feedstocks/raw materials

Biochar can be produced from various organic materials suitable as feedstock such as grass, cow manure, wood chips, rice husk, wheat straw, cassava rhizome, and other agricultural crop residues. The extensively used waste materials for biochar production are such as agricultural wastes (bark, straw, husks, seeds, peels, bagasse, sawdust, nutshells, wood shavings, animal beds, corn cobs and stalks, etc.), industrial wastes (bagasse), agroforestry (Gliricidia twig, Eucalyptus bark, Pongamia shell, Eucalyptus twig and Leucaena twig) and urban/municipal wastes. For biochar production, hard wood biomass with 10% moisture content is best.

Production process

Biochar production with thermochemical conversion technologies are mostly used than biochemical conversion technologies because the rate of hydrogen production and yield are relatively lower in the biochemical conversion technologies. Further, the thermochemical conversion technology divided into combustion, pyrolysis and gasification. Biochar produced by slow pyrolysis process from biomass waste such as agricultural, municipal, animal, or industrial sources, is highly porous, fine-grained, carbon dominant product with large surface area with oxygen functional groups and aromatic surfaces with the primary objective of soil improvement. The general temperature for pyrolysis ranges from 300 to 1000°C.

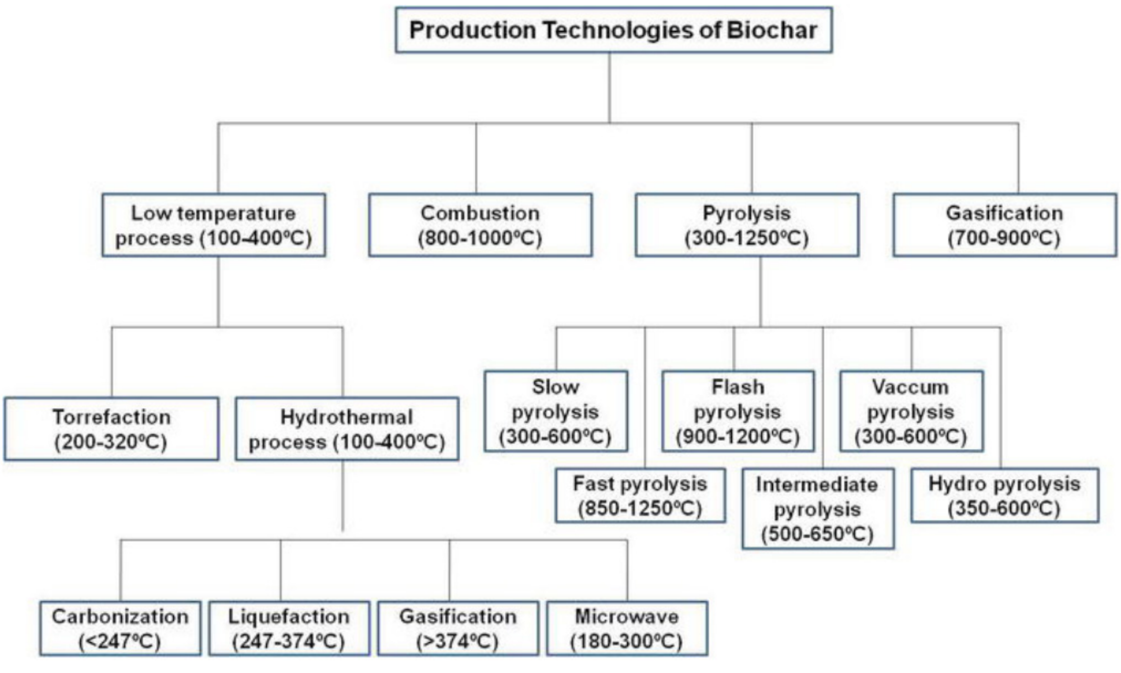

Fig.2 Different thermochemical processes for biochar production

Effect of biochar on soil health:

The biochar incorporation into the soil creates a direct impact on various soil attributes. The application of biochar is one of the sustainable approaches to improving the physical, chemical and biological properties of soil, the quality of produce and crops yield.

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Soil physical and chemical properties:

Biochar imparts a significant change in the physical characteristics of soils, resulting in a net increase of total soil-specific surface area and a reduction in the soil bulk density, consequently improvements in soil structure and aeration dynamics. One of the most important effects of biochar application as a soil amendment is the improvement of soil aggregate stability. Soil water retention is also improved by biochar uses due to its increased pore size and aggregate stability. Generally, biochar improves the soil physical condition over long term uses.

The application of biochar has a significant effect on the soil's chemical properties, *viz*., pH, EC, CEC and soil organic matter. Soil acidity may reduce through biochar application because of its high alkalinity, strong buffering properties and the presence of functional groups. It acts as an excellent adsorbent of plant nutrients and pollutants because of the surface characteristics and attached functional groups. Soil containing high CEC helps to bind plant nutrient cations to the surface of biochar particles, humus and clay, so nutrients are retained rather than leached out and therefore more available for uptake by plants. Organic matter content in saline soils is generally less and thereby less structurally stable. Hence, addition of organic additives such as biochar to these soils can reduce salt stress and enhance plant growth. Biochar application in soil naturally increases organic carbon content of soils as it is a carbon rich material. Biochar emerged as a valuable supplement for low-fertile soils to enhance soil organic content, and to mitigate climate change.

Soil biological properties:

Biochar enhances the crucial soil biological properties. The high internal surface area of biochar, increases the capacity to absorb organic matter which act as retreat for soil microbiota. The population of bacteria, actinomycetes and arbuscular mycorrhizal fungi increased due to incorporation of biochar and this microbiota reduce N loss and increase nutrient availability for plants. Biochar has also been resulted to improving the soil mycorrhizal population through the enhancement of soil carbon sequestration and the addition of soil fertility. Biochar-treated soil may impart a better condition for beneficial soil bacteria to perform well.

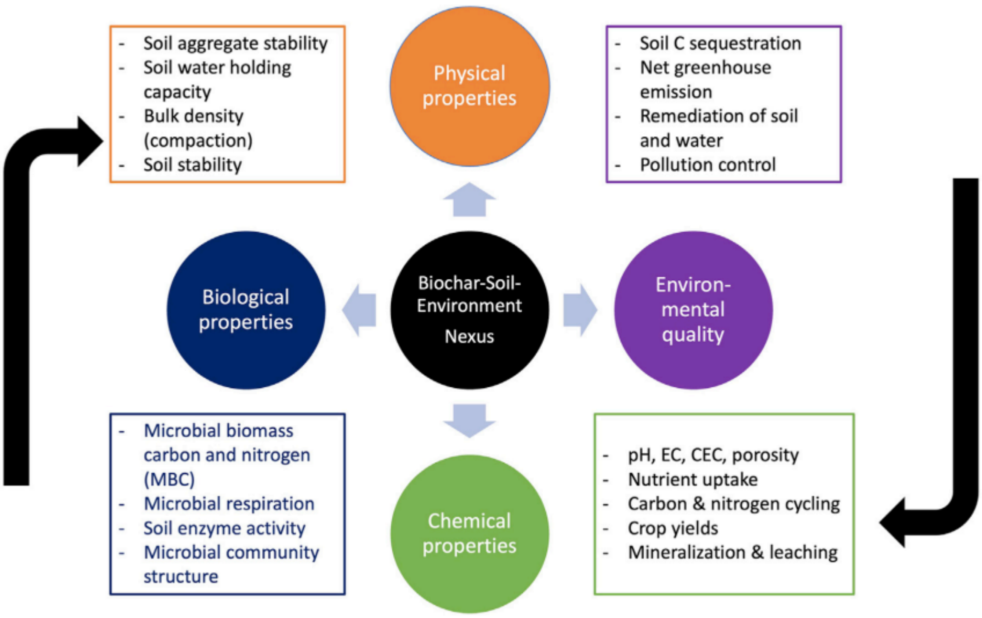

Fig. 3 Biochar in soil physico-chemical properties and environmental attributes

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Future perspectives of biochar:

Biochar applications in soil have the potentiality for sustainable agriculture. However, there are still some challenges and barriers that need to be addressed to recognize these potentials. More research is needed to better understand the long-term effects of biochar application on soil properties, crop yields, and environmental quality well as its impacts on soil microbial communities and greenhouse gas emissions.

Conclusion:

The awareness on soil health concept has increased among agriculturist and horticulturist regarding the importance of maintaining soil fertility, crop productivity and environmental quality over a long-term period. Biochar has positive effects on the physico-chemical and biological properties of soil, that means soil health directly and indirectly influenced with the application of biochar.

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