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BIOCHAR: AN ALTERNATE WAY TO ENHANCE SOIL HEALTH

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One of the main issues facing global agriculture is soil degradation, which includes declining fertility and increasing erosion. Continued and excessive soil cultivation may lead to many forms of soil deterioration, such as acidification, loss of organic matter, and major soil erosion. Moreover, the aggregate stability of soil is diminished by the decline in soil organic matter. Thus, it is essential to restore the degraded soils using inexpensive and environmentally friendly approaches. It is a byproduct of pyrolyzing biomass in an atmosphere lacking in oxygen. Biochar has a variety of functional groups and a porous carbonaceous structure. Pyrolysis-produced charcoal, or biochar, has a porous structure that is kept up well and has various inorganic nutrients, a sufficient number of functional groups, and carbon components that are stable. One resource that shows promise for managing soil fertility is biochar. Moreover, phosphate, nitrate, and ammonium-loaded biochar might be a slow-release fertilizer to improve soil fertility.

Microorganisms, agri-output, soil attributes, and nutritional values are all positively impacted by biochar. Because of its affordability, environmental friendliness, and versatility, biochar has shown to be a preferable option for agriculture. Biochar is essential for lowering greenhouse gas emissions and hence assisting in the mitigation of global climate change. It also helps to enhance soil quality and decrease contaminants. The hydraulic characteristics of soil can also be replaced by biochar. After applying biochar to the soil, the majority of the carbon may be recovered through the short-lived carbon cycle. Numerous physical and chemical properties of biochar influence how successfully it may introduce various bacterial species into the soil.

Physical and chemical properties of biochar:

Specific Surface area:

Is a crucial characteristic that affects the target species' catalytic activity and chemical kinetics while providing an active region for reaction. As the temperature of pyrolysis rises, the surface area of biochar also rises. High pore volume, extremely porous structure, and large surface area are considered as advantageous.

Density and porosity:

Particle density only takes closed, solid pores into account. Depending on the material used to produce the biochar, the pore size varies and typically ranges from nano (<0.9 nm), Micro (<2 nm), meso (2-50 nm) to macro spores (>50nm). nano, micro, meso, to macro spores.

Hydrophobicity and water-holding capacity (WHC):

Increasing the pyrolysis temperature increases the hydrophobic properties of biochar. Water cannot penetrate the porous structure of the biochar due to the hydrophobic surface present in the pores. Consequently, higher porosity is the cause of the variations in the amount of water to be absorbed.

Thermal conductivity and heat capacity:

The development of the porous structure of biochar results in a reduction in its thermal conductivity. The conductivity of biochar rises with carbonization temperature, acting as a protective barrier.

Grindability:

The char is more sensitive and has superior grindability than the raw material because of the mechanical stability that it maintains during the carbonization process.

pH-value:

A higher pH value is directly correlated with increased alkalinity. Biochar's pH value makes it useful for agricultural applications as soil conditioners. The primary factor affecting the pH value of "biochars" is temperature. connected to the biochars' higher pH. The pH of biochar is often found to be 7.

Reactivity:

The inorganic components help to increase the reactivity of the biochar because they can function as catalysts.

Carbon content:

The stability of biochar is excellent. feedstock and pyrolysis conditions have a significant impact on the chemical composition.

Structure:

The most prevalent elements, C, H, O, and N, are often responsible for the main structural components of biochar.

Surface functional groups:

On the surface of biochar, a number of functional groups, including hydroxyl, amino, ketone, ester, methyl aldehyde, and carboxyl, develop. The release of hydrogen and oxygen is a crucial step in the carbonization process, which is the breakdown of biomass structures by heat that separates functional groups. Functional groups with oxygen, a sign of strong complex formation with metal cations.

Cation exchange capacity:

Oxygenated functional groups which are abundant in low temperature biochar and suggests high complex formation intensity with metal cations, contribute to the biochar's overall high CEC.

Non-Organic content:

The non-organic portion of biochar, which includes components like Mg, Ca, O, N, S, and K, is called the ash content.

Biochar production technologies:

The various methods are used for biochar production viz., Fast pyrolysis; Slow pyrolysis, Torrefaction, Hydrothermal Carbonization and Gasification.

Torrefaction: It is the process of converting feedstocks thermally into solid components under anaerobic circumstances at 200–300 °C and atmospheric pressure. Pre-treatment, either dry or wet, is applied in this thermal process to boost the quality of the finished product by removing different volatile chemicals (moisture, carbon dioxide, and oxygen) through decomposition. The isothermal features of food waste torrefaction were investigated between 200 and 300 ◦C for 60 and 180 min. The amount of carbon, energy density, and caloric content of food waste increase with a constant temperature increase of 15 ◦C/min.

Slow pyrolysis: Slow pyrolysis, which converts resistant carbon into a variety of compounds, is a promising carbon-negative process for producing biochar from different bio-stuffs. It also lowers the amount of CO2 in the atmosphere. A temperature range of 350 ◦C to 600 ◦C is used for slow pyrolysis, with a heating rate of 5 ◦C per minute. The breakdown of cellulose and hemicelluloses requires the supply of heat. Slow pyrolysis can be carried out with agricultural waste. It is used to maximize the solid product of biochar, which is done in a lab setting with a slow pyrolysis technique.

Fast pyrolysis: To increase the production of bio-oil by up to 75%, fast pyrolysis is carried out at 800 ℃ to 1300 ℃ with a heat rate of 200 ℃/min for no more than 10 s. This technique uses ablative, rotating-cone, bubbling fluidized bed, and circulating bed reactors.

Gasification*:* Gasification is a conversion process that uses a regulated oxidizing agent (air, oxygen, and steam) to transform a carbon source into a gaseous product (syngas) at a temperature below 70 °C. About 10% of the biomass is produced at the end, which is less than that of pyrolysis.

Application of biochar

The application of biochar in agricultural soil enhances the soil structure, which in turn improves the soil's physiological, chemical, and biological properties, aiding the agricultural soil in increasing its capacity to absorb nutrients.

- **Enhance the soil's properties:** The use of biochar in agricultural soil improves the soil structure, which in turn improves the soil's physiological, chemical, and biological characteristics, aiding the agricultural soil by improving its capacity to absorb nutrients.

- **Improvement in fertility status by increasing nutrient availability:** Biochar minimizes the soil salinity, enhances ion exchange capacity, and elevates the soil nutrients in the soil.
- **Soil remediation:** It is an economical, environmentally sustainable solution made from waste to restore the soil. Additionally, because of its large surface area, higher water-holding ability, and highly porous nature, it altered the soil properties and thereby increased crop output.
- **Induces microbial activity in the soil:** Because biochar acts as a medium for the bacteria, it promotes microbial development in the soil. The use of biochar affects the habitat and activities of other soil organisms, such as mycorrhizal fungus, which directly improves the quality and health of the soil.
- **Agronomical importance**: Biochar has a favorable effect on agricultural production and output. It improves the crops' capacity to access and utilize nutrients.
- **Climate change mitigation:** Remarkable physical and chemical properties make biochar useful in a variety of applications to enhance the natural environment. Since biochar collects transition metals, it can be used as a catalyst to aid in the breakdown of pollutants.

  Carbon sequestration: Because its carbon component is typically stable, biochar was first proposed as a soil additive to store carbon in the soil, improving carbon sequestration.
- **Mitigate greenhouse gas emissions:** Global use of biochar has been estimated to cut greenhouse gas emissions by 12%.

Conclusions:

Biomass is manufactured under conditions that give it heterogeneous physical and chemical features; it is often pyrolyzed under various conditions. Crop productivity is directly increased by using biochar to improve the soil's texture and composition, soil productivity, and nutrient absorption. Additionally, biochar aids in the removal of toxic soils, improves plant photosynthesis, increases carbon sequestration, lowers greenhouse gas emissions, and lessens the island effect. In addition, biochar is easily transportable and less expensive than chemical fertilizers. Therefore, in order to quickly use biochar in affected fields, farmers, soil scientists, researchers, and relevant authorities must work together more.

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