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Biochar from Jute and Mesta: A Promising Tool for Sustainability

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Residue management is a common setback and environmental hazard faced by marginal farmers owing to lack of suitable machinery for crop residue incorporation, problem of seeding in the standing crop, low turn around period. Residue burning provides a fast way of controlling weeds, insects and diseases, by altering their natural habitat but leads to deterioration in soil properties, loss of nutrients like N and S, organic matter and microbial activity required for maintaining better soil health in the long run. Again, maintenance of a threshold level of organic matter in the soil is imperative for maintaining physical, chemical and biological integrity of the soil and also for the soil to perform its agricultural production and environmental functions. Hence, conversion of biomass to biochar is the most profitable alternative to manage soil health and fertility.

Pyrolysis of biomass under controlled conditions into biochar, provides a novel residue management option with long-term carbon stabilization. Biochar, also called soil conditioner or zero waste, is a fine-grained, carbon-rich, porous product remaining after plant biomass has been subjected to thermo-chemical conversion process (pyrolysis) at low temperatures (~350–600°C) in an environment with little or no oxygen. Biochar, due to its aromatic structure and long mean residence time in the soil (more than 100 years) has the potential for long-term carbon sequestration in the soil. Biochar is not a pure carbon, but rather mix of carbon (C), hydrogen (H), oxygen (O), nitrogen (N), sulphur (S) and ash in different proportions (Masek, 2009). Now a days biochar technology is considered as geo-engineering solution because it has capability to reduce the atmospheric greenhouse gases and lower carbon footprint. As a soil amendment, biochar creates a recalcitrant soil carbon pool that is carbon-negative, serving as a net withdrawal of atmospheric carbon dioxide stored in highly recalcitrant soil carbon stocks. Thus, biochar application to soils has been recommended as an important climate-smart soil management practice in modern global agriculture.

Diversified and alternate utilization of plant biomass is a growing area of research and development for sustainable use of natural resources. The jute and allied fibre crops like mesta produce high biomass (40-60 t/ha), which make them a potential candidate for biomass utilization and alternate product development. Presently only a small portion (2.5-3.0 t/ha) of biomass is commercially utilized as fibre, while some part of the residual biomass (jute sticks) is utilized for low-efficiency burning stock. Utilization of whole biomass would increase the profitability of jute farmers at least by 40% and allow better utilization of the total biomass. In India, annually about 27 lakh tonnes of jute and mesta stick are produced as byproduct of raw jute cultivation. These residues are either partially utilized or un-utilized due to various constraints. Moreover, cultivation of jute and mesta as fibre crops is becoming less remunerative due to high cost of interculture operations, non-availability of quality retting water and fluctuating market price. Biochar production would benefit farmers to obtain higher income in addition to environmental sustainability. It has been estimated that around 7.5 lakh tonnes of charcoal can be produced from this jute and mesta sticks worth Rs 4914 crores annually.

Biochar from jute has the potential to increase conventional agricultural productivity and enhance the ability of farmers to participate in carbon markets beyond the traditional approach by directly applying carbon into the soil. The direct effect is explained by the fact that biochar being concentrated during pyrolysis contains higher amount of nutrients than the biomass from which they are prepared. The indirect effect is due to improvement in soil physical, chemical and biological properties due to biochar application. The central quality of jute biochar that makes it attractive as a soil amendment is its highly porous structure, potentially responsible for improved water retention and increased soil surface area. Biochar prevents oxidation of the material that would otherwise have been degraded to release CO_2 into the atmosphere. Converting waste biomass into biochar would transfer very significant amounts of carbon from the active to inactive carbon pool, presenting a compelling opportunity to intervene in the carbon cycle. The use of biochar as soil amendment is proposed as a new approach to mitigate man-induced climate change along with improving soil productivity. Such partially burnt products, more commonly called pyrogenic carbon or black carbon, may act as an important long-term carbon sink because their microbial decomposition and chemical transformation are probably slow. Use of biochar will minimize the environmental pollution, add benefits of C sequestration by virtue of its high biomass, improve soil health and soil quality and will help in phytoremediation of heavy metals if grown in contaminated site. Moreover, biochar application will increase conventional agricultural productivity and mitigate GHG emissions from agricultural soils. Biochar production will generate additional employment and hence provide financial security to the farmers.

Carbon sink and sequestration

Biochar that is stable, fixed and recalcitrant carbon can store large amounts of greenhouse gases in the ground for centuries, potentially reducing or stalling the growth in atmospheric greenhouse gas levels; at the same time its presence in the earth can improve water quality, increase soil fertility, and raise agricultural productivity. Soil contains 3.3 times more carbon than atmosphere and 4.5 times more than plants and animals. This makes soil an important source of greenhouse gases but also a potential sink if right management is applied. The use of jute crop residues for bio-energy production reduces carbon stocks in cropland. If biochar is returned to agricultural land it can increase the soil's carbon content permanently and would establish a sink for atmospheric CO_2. The carbon in biochar resists degradation and can hold carbon in soils for hundreds to thousands of years The use of crop residues as a potential energy source improve soil quality and reduce greenhouse gas emission in a complementary not competing way. Biochar and bioenergy coproduction can help combat global climate change by displacing fossil fuel use and by sequestering carbon in stable soil carbon pools. It may also reduce emissions of nitrous oxide. Under field conditions, biochar reduces methane emission up to 90% as compared to non-amended and residue incorporated soils indicating towards the biochar's potential to mitigate climate change by reducing the negative effects of green house gasses from the soil. Biochar may suppress CH4 emissions by increasing soil pH while influencing microbial activities and at the same time biochar also improves soil aeration and increases oxygen content resulting in an increase in soil redox potential making conditions favourable for methanotrophs and decrease in CH4 emissions. Biochar may reduce emissions of nitrous oxide either by inhibiting soil microbial activity, alter microbial community composition, or change the partitioning of N through proteolysis, ammonification, or nitrification pathways, and subsequently reduce N assimilation by microbes resulting in decreased mineralization.

Soil Conditioner

This practice converts agricultural waste into a soil enhancer that can hold carbon, boost food security, and increase soil biodiversity and discourage deforestation which will help to increase microbial activity, water retention capacity of soil, reduce nutrient leaching, enhance uptake of nutrients by roots, increase pH of acidic soils, alter soil texture and structure and reduce the need for chemical fertilizers. Incorporation of biochar to soil increases the NH_4^+ adsorption subsequently decrease nitrification which in turns conquer the discharge of H^+ concentration to the soil and relieve soil acidification. The intrinsic CEC of biochar is higher than whole soil, clays or soil organic matter. Biochar addition increases soil CEC most probably due to high surface area, high porosity, possess inorganic materials of variable charges having potential to increase soil CEC and base saturation. Biochar itself has very low bulk density which is supposed to increase the soil pore volume mainly attributing to the dilution effect of a low bulk density amendment to the soil although the biochar also has the significant effect on macroaggregate formation. The biochar acts as a sink, limiting theavailability of NH_4^+–N to heterotrophic and autotrophic microbes (nitrifiers). This suggests that an important influence of biochar on soil processes results from its capacity to sequester inorganic N, primarily NH_4^+ and ultimately the nutrient loss from the soil can be minimized. Biochar is a desirable soil material in many locations due to its ability to attract and retain water. This is possible because of its porous structure and high surface area. Where biochar is applied, soils show higher water-holding capacity, improved water retention, increased plant-available water, increased plant resilience in drought conditions, and greater crop productivity per unit of water. Biochar acts as a habitat for many beneficial soil microorganisms, thereby increasing the soil microflora and fauna. High surface area and hydrophobicity of biochar are known to facilitate better activity, higher retention, and microbial diversity. Biochar also contains some aromatic hydrocarbon compounds which sometimes suppress the bacterial population while increasing the fungal growth. Biochar has the ability to improve the earth's soil resource by increasing productivity and crop yields by reducing the need for some chemical and fertilizer inputs and potentially providing other soil benefits. Applied to the soil in a finely ground form, biochar's vast surface area and complex pore structure provides a secure habitat for beneficial microbial activity that is important for crop to flourish. As the biochar have ability to retain the nutrient by means of adsorption on high surface area and high CEC due to development of surface charges, less fertilizer needs to be applied which reduces the cost of producing the crop.

Renewable Energy Resource

If biochar is used for the production of energy rather than as a soil amendment, it can be directly substituted for any application that uses coal. Pyrolysis also may be the most cost-effective way of electricity generation from biomaterial, i.e. sustainable biochar practises can produce oil and gas by products that can be used as fuel, providing clean renewable energy on long term basis.

Waste management by disposal and recycling

Farmers burn most waste biomass at the farm level by a technique called as slash and burn. This farm waste can be collected to produce biochar. This would prevent the harmful release of greenhouse gases at the same time it would be ecology clean and efficient way to manage waste related problems. Besides, it enhances soil and water conservation in rainfed areas.

Conclusion

Efficient use of biomass by converting it to a useful resource (highly stable carbon compound known as biochar) of soil amendment/nutrients is one way to manage soil health and fertility. Biochar from jute and mesta can enhance natural rates of carbon sequestration, reducing waste, improve the soil quality, conventional agricultural productivity, soil physical properties, nutrient availability, soil microbial activities, crop productivity and mitigate GHG emissions from agricultural soils. To promote the application of biochar as a soil amendment and also as a climate change abatement option, research, development and demonstration on biochar production and application in agriculture system, it is necessary to develop low-cost biochar production units to make the technology affordable for small and marginal farmers.