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Biochar for Soil Health Enhancement and Crop Productivity Improvement

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Most of the crop residues, agro-industrial wastes and agricultural by-products create management problems to farmers in agronomic practices in fields. If these materials, will convert into biochar by pyrolysis technique, then it may be a significant opportunity for maintaining soil health as well as crop productivity. Biochar positively affect the physical, chemical and biological properties of soil, but, effects were varied from soil to soil. Physical and chemical characteristics of biochar depend upon types of feed stocks and pyrolysis conditions. There is need of future research for promoting the use of biochar on large scale. It is essential to make low-cost and eco-friendly production unit of biochar for farmers to exploit potential of biochar.

Introduction

Crop residues generally creates management problems to the farmers at farm as well as in land in different manners, such as difficulty in field preparation, irrigation, making bunds and disposing in different places. Abundantly available crop residues are straws of paddy, wheat, millet, sorghum, maize, pigeon pea, castor, mustard, stover and cobs of maize, cotton and jute sticks, sugarcane trash, fibrous materials, roots and branches of many other crops. In the same way, agricultural by-product and agro-industrial residues are existing in huge quantities like rice husk, mustard husk, coffee husk, shell of groundnut, cotton waste, shell of coconut, coir pith, shell of tamarind, cassava peels, sugarcane bagasse, tea waste, casuarina leaf litter, silk cotton shell, oil palm fibre and shells, cashew nut shell, coconut shell and coir pith etc.

Need for recycling of crop and agroforestry residue into biochar for use in Indian agriculture

- To improve soil health through efficient use of crop residue as a source of soil amendment/nutrients.
- To improve soil physical properties viz., bulk density, porosity, water holding capacity, drainage etc, through incorporation of biochar
- Substantial amounts of carbon can be sequestered in soils in a very stable form
- Addition of biochar to soil enhances nutrient use efficiency and microbial activity

- To enhance soil and water conservation by using the biochar in rainfed areas
- Minimize reliance on external amendments for ensuring sustainable crop production
- Mitigation of greenhouse gas emissions by avoiding direct crop residue burning by farmers
- To enable destruction of all crop residue borne pathogens
- Conversion of residues into biochar helps to reduce the bulkiness both in terms of weight and volume and make the product easier to handle compared with that of fresh and uncarbonized crop and agroforestry residue.

Characteristics of Biochar

Application	Chemical properties
• Pollutant absorption • Soil remediation carbon sequestration • Decontamination of water • Catalyst	• High cation exchange capacity • Surface functional group • High mineral content • Neutral to high pH
Preparation route	**Physical Properties**
• Pyrolysis • Hydrothermal carbonization • Gasification	• High Surface area • High Surface Charge • High Porosity • Low Bulk density

Technical Details of Biochar Production in India

Feedstock Selection

- **Agricultural Residues:** Rice husk, crop stalks (wheat, maize, sugarcane), coconut shells, and other agricultural waste form the majority of feedstock sources.
- **Municipal Solid Waste:** Some initiatives aim to utilize the organic fraction of municipal solid waste for biochar production.
- **Forestry and Timber Byproducts:** Wood chips, sawdust, and other residues from timber processing are suitable feedstocks as well.

Pre-Processing

- **Drying:** Feedstock is typically dried to reduce moisture content. Optimal moisture content ranges from 10% to 15% for most processes.
- **Size Reduction**: Large biomass may need to be chopped or chipped for efficient pyrolysis.

Production Methodologies

Biochar is the charred biomass produced by slow pyrolysis in which organic ma- terial is heated under controlled temperatures (300-500°C) in the absence of oxygen. The biochar produced should have high carbon content (>60% C; H:C molar ratio should not exceed 0.7). Various pyrolysis technologies are commercially available that yield different proportions of biochar depending upon the residues used for production under varying operating conditions.

In India low cost technologies have been developed by some institutions having minimal control over temperature and time parameters. Biochar can be successfully made using these methods provided H:C molar ratio of final product is<0.7. Some of the commonlyused methods in India are described as under:

Heaping and Charring

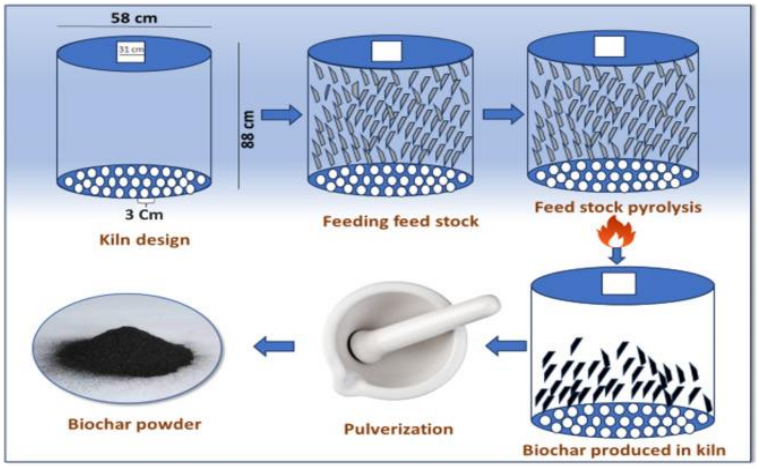
In heap method biomass such as wood lopping, small wood logs, twigs, woody crop residues etc. is piled up to a height of about three to four feet and is covered with mud paste. Vents are opened starting from the top and

working downwards on drying of mud paste. The heap is set at fire from one end and let to smoke for a considerable time period usually in few days to week. Biochar is formed under

oxygen stress conditions but there is no perfect control over temperature and air.

Biochar Kiln

a) Holy Mother Biochar Kiln developed by Sarada Matt, Almora, Uttarakhand, India



in which bricks and clay are used in the construction. The biomass is added continuously as the fire continues. Air is allowed to flow from bottom as long as biomass is added con- tinuously while burning. As the biomass reaches the level just below the secondary air vents, further addition of biomass is stopped and then the bottom vent is also closed. After some time, water is sprinkled to extinguish the fire. The biochar is collected after some time. Biochar is formed under oxygen stress conditions but there is no perfect control over temperature.

b) ICAR-CIAE biochar kiln: ICAR-CIAE has also developed different designs of biochar kilns for preparation of biochar. These designs vary with a small capacity of about 500 g to as high as 5-10 kg biochar.

Drum Method

- Various forms of drum have been developed by different organizations. Some have developed them in horizontal and others have made it as vertical equipment. Also some require external heating, the other may need initial sparking for burning. There is hardly any control over the temperature and air supply. Also the pyrolysed biomass may not be uniform. The ash content in the biochar is also high. Following are some of the drums used.

Standard Biochar Production Units

- Systematic biochar production has been attempted at few locations. ICAR-Research Complex for NEH Region at Barapani established pyrolysis plant that has a capacity to use 300 kg offeedstock. Similarly ICAR-CIAE Bhopal has designed a biochar plant for a smaller quantity of biochar production. It does not require any initial ignition. Only electric heaters are installed for pyrolysis the biomass. In this kiln there is control over temperature. The smoke is also disposed off safely.
- MPUAT Udaipur has developed a batch type continuous torrefaction unit using a suit- able gear motor. It can torrefy about 15-20 kg of crop residues per hour. There is gen- eration of considerable amount of gases also (Anonymous, Annual report CIAE 2017- 18). MPUAT has also developed system of continuous screw type biochar production of 20 kg d1 capacity. Using groundnut shell it can produce 6 kg biochar per hour.

Post-Processing

- **Cooling and Quenching**: Biochar is cooled and quenched to prevent continued carbonization and combustion.
- **Sizing**: Biochar may be crushed or ground depending on intended applications.
- **Activation**: Additional treatment may be applied to enhance biochar's surface area and adsorption capacity.

Method of Application

Like any other organic amendments, Biochar can be applied to soil by different methods including broadcasting, band application, spot placement, deep banding etc. However, the method of biochar application in soil depends on the farming system, available machinery and labor.

Conclusion

Generally most of the crop residues create problem in managing the crops in fields. These residues do not have any judicious use. If these residues are converted into biochar by suitable technology, then it might play very important role for enhancing the status of soil health. Currently, several institutes are doing research on biochar preparation from different types of biomass and its effect on soil quality and crop productivity. Several results revealed that addition of biochar to soil improved soil health and crop productivity. Nevertheless, to encourage the use of biochar as a soil amendment, some policy on biochar production and application is very vital. It is essential to construct low-cost and eco-friendly biochar production unit for small and marginal farmers.

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