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Harnessing Biochar, Algae and Biodegradable Films for Sustainable Agricultural Production in Rainfed Areas

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Abstract

Rainfed agriculture is highly dependent on timing and duration of rainfall making crop production vulnerable to prolonged dry periods. Jammu's Kandi belt receives very low rainfall posing as a challenge for farmers increasing the need for locally adaptable approaches to sustain food production. Biochar, a locally producible carbon-rich material obtained through pyrolysis of agricultural residues, has the potential to improve soil structure, nutrient retention and long-term carbon storage, thereby supporting productivity and resilience in rainfed smallholder systems. Biodegradable films which are an alternative to plastic mulch can be used to conserve moisture and suppress weeds. Cyanobacterial biofertilizers cultivated through simple on farm methods provide a low-cost route to improve soil health which can help in reducing the over dependence on chemical fertilizers. This review brings these three approaches together to outline a practical pathway toward more resilient rainfed farming.

Keywords: Biochar, Biostimulants, Cyanobacteria, Pyrolysis

Introduction

India is among the world's major agricultural producers, with food-grain production reaching hundreds of millions of tonnes annually. However, can this pace be sustained while meeting the growing food needs of the world's most populous country?

Rainfed agriculture, which depends primarily on rainfall, accounts for a large share of the world's cultivated land and contributes substantially to global food production. It is vulnerable to water scarcity, nutrient depletion and rainfall variability (Rockström *et al.*, 2003). In India, rainfed agriculture occupies about 60% of the agricultural area, while the Jammu region's 'Kandi' belt faces additional challenges because of its relatively dry and hot conditions in the Himalayan foothills. Excessive or inappropriate use of chemical inputs can contribute to soil degradation and increase production costs. As India promotes more sustainable and natural-resource-efficient farming practices, innovative and locally adaptable solutions are needed to improve productivity and resilience.

Biochar: A Sustainable Soil Enhancer

Biochar is a carbon-rich material produced by heating biomass under oxygen-limited conditions through pyrolysis. Depending on its properties and application, biochar can improve soil physical and chemical properties, support nutrient retention and contribute to long-term carbon storage (Lehmann and Joseph, 2015). Using agricultural residues as feedstock can also provide a productive use for farm waste.

On-Farm Biochar Production

Suitable feedstocks may include rice husks, maize stalks, wheat straw, sawdust and other clean plant residues. A suitable pyrolysis unit, such as a purpose-built kiln or drum, is required. The biomass is heated under limited oxygen so that it is converted into a stable, black, carbon-rich material rather than being completely burned. After pyrolysis, the biochar should be allowed to cool completely before handling. It can then be crushed and mixed with compost or well-decomposed manure to enrich it with nutrients before soil application. Production methods should be adapted to local conditions and carried out with appropriate safety precautions. The general steps involved in the preparation and application of Biochar are illustrated in figure 1.

Article History

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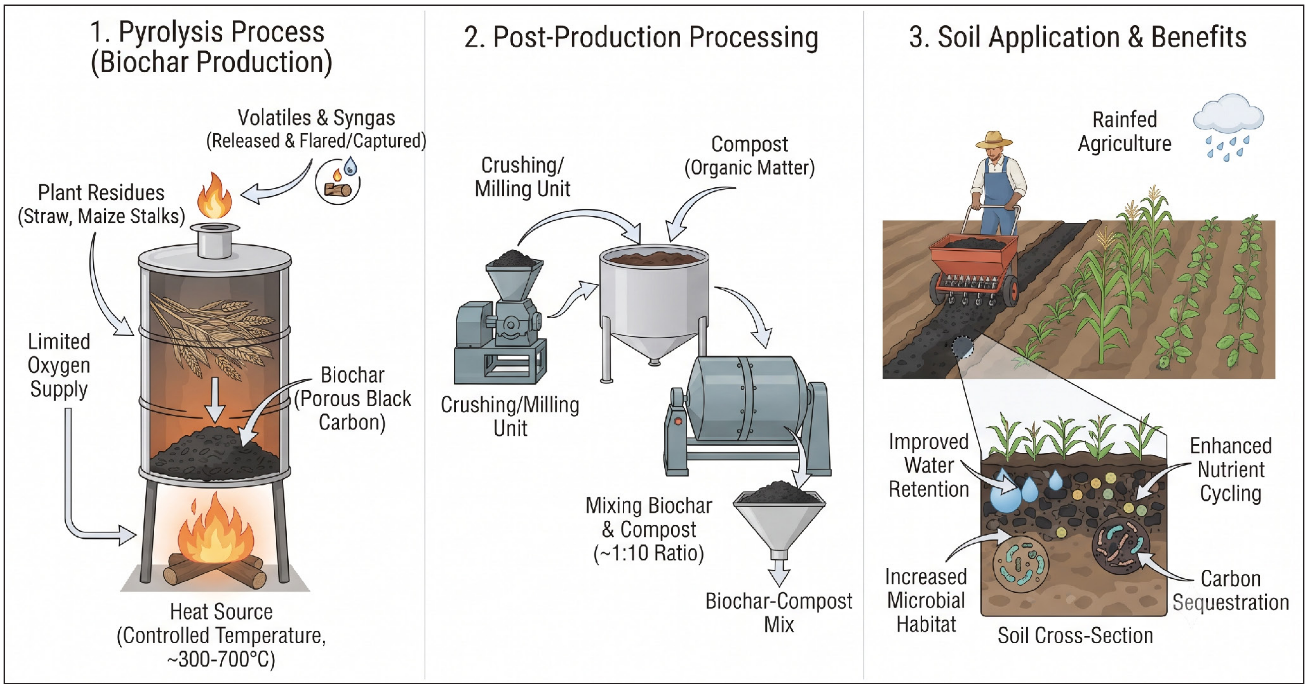

Figure 1: Preparation and application of Biochar

Algae: A Potential Biological Input for Sustainable Agriculture

Cyanobacteria, including nitrogen-fixing genera such as *Nostoc*, *Anabaena* and *Tolypothrix* spp. can contribute to sustainable agriculture through biological nitrogen fixation, production of growth-promoting compounds, nutrient cycling and interactions with soil microorganisms. Their use as biofertilizers or biostimulants has potential to improve soil health and crop performance, although the effectiveness depends on the organism, crop, soil and environmental conditions. Research on cyanobacteria and other algal resources supports their potential role in sustainable agricultural systems (Pathak *et al.*, 2018).

On-Farm Algal and Cyanobacterial Production

Production systems should use species and strains appropriate for the intended agricultural purpose. Cyanobacteria can be cultivated in suitable water-based systems under controlled conditions, with appropriate nutrients, light, temperature and pH. The culture should be monitored regularly for contamination and harvested according to the characteristics of the organism and the intended application. Azolla should not be described as an alga: it is a small aquatic fern (*Azolla pinnata*, *Azolla filiculoides*) that hosts the nitrogen-fixing cyanobacterium which can be used as a nitrogen-rich biological input in some farming systems. Similarly, Spirulina is more accurately described as a Cyanobacterium (*Arthrospira plantensis*).

Biodegradable Films: Moisture Conservation and Weed Control

The original draft uses the term 'biofilms' for thin agricultural films used as mulch. These are better described as biodegradable mulch films, because microbial biofilms and biodegradable polymer films are different materials. Biodegradable mulch films can help conserve soil moisture, suppress weeds and reduce evaporation, while offering an alternative to conventional polyethylene mulch in appropriate systems. However, their performance and rate of degradation vary with film composition and field conditions, so claims about specific percentages of evaporation or weed reduction should be supported by crop- and site-specific evidence (Rosseto *et al.*, 2019; Liu *et al.*, 2021).

On-Farm Production of Starch-based Biodegradable Films

Starch-based biodegradable films can be developed using materials such as maize, cassava, or potato starch, often combined with a plasticizer or a protein-based component such as gelatin. The starch is dispersed in water and heated to form a paste, after which the other components are incorporated. The mixture can be cast onto a flat surface and dried to form a film. Before field application, the film should be evaluated for strength, water resistance, biodegradability and suitability for the target crop and soil conditions. Starch-gelatin films have been investigated as potential alternatives to conventional agricultural plastics (Rosseto *et al.*, 2019).

Conclusion

Soil health and agricultural productivity can be improved through appropriate, evidence-based technologies, but farmers need practical training and reliable information before adopting them. To achieve tangible results, it is essential to provide clear instructions and credible information at the grassroots level, in local languages and to demonstrate the technologies under local conditions. Training farmers in on-farm production techniques, along with ensuring access to quality inputs and appropriate technical support, will be important for bringing about meaningful change.

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