Carbon-negative biochar from weed biomass for agricultural research in India

Biochar is a carbon-rich charcoal-like substance obtained by heating biomass in limited oxygen condition, through a process known as pyrolysis. If biochar is buried into the soil for carbon credits and crop enhancement, then the pyrolysis process can be carbon negative. When the process of producing biochar sequesters more carbon than it emitted, it is carbon negative[1]. Locally available weed biomass which is not economically important and causes crop loss can be used as an important source for the preparation of biochar. Thus, if we prepare biochar from locally available weeds, then it is possible to reduce the weed population in the agricultural field, which is a serious problem in organic agriculture since use of any chemical herbicide is not permitted. It can enhance plant growth by improving soil physical (i.e. water-holding capacity, bulk density, porosity, infiltration), chemical (i.e. nutrient retention, nutrient availability, pH), and biological characteristics (i.e. enzyme activity, microbial biomass carbon), all contributing to increased crop production and productivity. Saturated hydraulic conductivity of the topsoil can be improved by biochar application. In sandy soil it also increases the water-holding capacity. The unique property of biochar which makes it an attractive soil amendment is its highly porous structure. This is responsible for increased water-holding capacity and nutrient retention capacity. The pores in biochar provide suitable habitat for soil microbes by protecting them from predation and drying, and also provide carbon, energy and mineral nutrient sources.

Using locally available weed biomass for making biochar provides a unique opportunity to landholders to improve soil health for a longer period of time (Figure 1). The production of biochar from weed biomass/farm waste and its application in soils may offer financial benefits with carbon credit[2]. It should be applied in the field every year along with other inputs like compost, manure, etc. to realize the economic benefits. During conversion of organic residues/weed biomass into biochar, landholders can also obtain some energy yield by capturing energy given off during its production process. In hilly areas like Sikkim soil loss, weathering and degradation occur at unprecedented rates, which causes imbalance in ecosystem properties. Biochar can play a major role in organic agriculture for sustainable soil health by improving existing best management practices, not only by decreasing nutrient loss through leaching but also improving soil productivity.

To neutralize acidic soils, farmers apply large amounts of lime/dolomite to farm soils at high cost. Biochar is basic in nature (pH > 7.0). If some basic materials are added into acidic media, then pH of those materials will increase. This dynamic nature of biochar affects the soil pH. It can react similar to agricultural lime, i.e. increasing soil pH. If a soil has low cation exchange capacity, it is not able to retain nutrients; the nutrients are often washed out through leaching by percolating water. In its pores having large surface area, biochar develops negative charges and provides more negatively charged sites for cations to be retained when added to the soil. On the surface of biochar, the negative charge which

Figure 1. Biochar prepared from locally available weed biomass.

develops can easily buffer soil acidity (as does organic matter). Generally landholders/farmers apply biochar in their own field only by hand. Considering human health, due to prolonged contact with airborne biochar particulates, it is not viable on a large scale. Deposition of biochar directly into the rhizosphere is a more suitable method of application. Mixing of biochar with compost, manure and other organic inputs will reduce odour and also improve nutrient availability over time due to slower leaching rate. Mixtures may be applied for uniform topsoil mixing without incorporation[3].

Till date, there is no specific rate of application of biochar in the soil. It depends on many factors such as biomass type used, type and proportion of nutrients (N, P, K, etc.), climatic and topographic factors of the land, and degree of metal contamination in the biomass. It has been found that application of biochar 5–10 t/ha, i.e. 0.5–1 kg/m^2 is a better option. Assuming that biochar is rich in nutrients, even low rates of biochar application can significantly increase crop productivity. In conclusion, in view of the unique property of biochar, it may serve as an important tool for agricultural researchers to mitigate climate change. It may be explored as an example of how a lesser important waste material that is produced as a by-product of burning of fuel can benefit the agricultural system through scientific technology.

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Need for phytolith-occluded carbon research in India

Mitigation of climate change is a human intervention aimed at reducing the sources or enhancing the sinks of greenhouse gases. Developing technologies to reduce the rate of increase in the atmospheric concentration of carbon dioxide (CO_2) from annual emissions of 11 Pg C yr^{-1} from energy, process industry, land-use conversion and soil cultivation is an important issue of the 21st century[1]. The ability of biotic sequestration and especially terrestrial systems to sequester and store atmospheric CO_2 has been recognized as an effective and low cost method of offsetting carbon emissions. Among the most promising approaches of long-term atmospheric CO_2 sequestration is terrestrial biogeochemical carbon sequestration[2,3]. Phytoliths, also referred to as plant opal, are silicified features that form as a result of biomineralization within plants[4]. They are present in most plants and range in concentration from 0.5% or less in most dicotyledons, 1–3% in typical dry land grasses, and 10–15% in Cyperaceae, and different species of Poaceae, including bamboos[2,5]. Recent studies have revealed that phytoliths contain 0.2–5.8% of phytolith-occluded carbon (PhytOC)[4,6–8], are highly resistant against decomposition and may accumulate in the soil as a fraction of soil organic matter (SOM) for several thousands of years after plant decomposition[4], demonstrating the potential of phytoliths in the long-term biogeochemical sequestration of atmospheric CO_2. Therefore, bio-mineralization of silicophytoliths is an important process as it influences the earth carbon cycle by occlusion of carbon during the silicification process[9].

Keeping in view the high concentration of phytoliths in certain herbaceous grass and woody bamboo species reported from China and elsewhere[2,8,10], a similar work can be initiated in India. In the Indian context, bamboo (Poaceae: Bambuseae) with 136 different species[11] dominates forests as wet, moist and secondary moist bamboo brakes[12] and covers 2.25% of total geographical area (TGA) of the country[13]. On the other hand, with 15 different grassland types, grasslands cover an area of 92,300 km^2 (3% of TGA) in India[13]. Bamboo forests and grasslands together represent ~5% of TGA of the country, and therefore this vast geographical area can form an important terrestrial landscape for PhytOC sequestration and management. Very little, if any, research in this direction has been carried out to explore phytolith concentration and PhytOC stock in bamboo forests and grasslands in India. Realizing the fact that all the species do not have high potential for phytolith concentration and therefore PhytOC stock, it is the need of the hour to identify potential species of herbaceous grasses as well as woody bamboo species. Identification of high phytolith content species will enable us to manage terrestrial ecosystems with such species to enhance PhytOC sequestration to set-in-motion the mitigation of climate change through removal of atmospheric CO_2 in a cost-effective manner. Furthermore, development of management strategies to increase production of PhytOC from the identified species will further advance the climate change mitigation programmes. However, there emerges a point that preponderance of only those species with high concentration of phytoliths can alter the spectrum of natural biodiversity and undervalue the possible benefits that can be offered by low-concentration phytolith species. Many of these environmental concerns and especially biodiversity conservation can be avoided without affecting structure and function of other terrestrial ecosystems by promoting high phytolith species as planting material for (i) reclamation of degraded lands and river banks, (ii) established and newly constructed road and railway tracks, etc.

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