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Biochar: Way to Climate Change Mitigation

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Climate change is the burning issue of 21st century and is largely caused by the increased concentrations of Green House Gases in the atmosphere occurring as a result of actions such as fossil-fuel burning and deforestation. The global average carbon dioxide set a new record high in 2022: 417.06 ppm. Atmospheric carbon dioxide is now 50 percent higher than it was before the industrial revolution. Increased GHG concentrations in the atmosphere affect the Earths radiative balance which causes temperature changes in the atmosphere and subsequent changes in other climate systems. A sustainable soil amendment such as biochar is among the many agricultural practices that can help farmers in mitigation and adapt to the climate crisis.

Biochar is the carbon-rich solid formed by heating biomass in an anaerobic environment, a process called pyrolysis. This pyrogenic carbonized material is typically known as biochar when it is intended as a soil amendment or to provide related environmental benefits.

Biochar helps build organic carbon in soil by up to 20% (average 3.8%) and can reduce nitrous oxide emissions from soil by 12 to 50%, which helps in the climate change mitigation. It found average crop yields increased from 10 to 42%, concentrations of heavy metals in plant tissue were reduced by 17 to 39% and phosphorous availability to plants also increased.

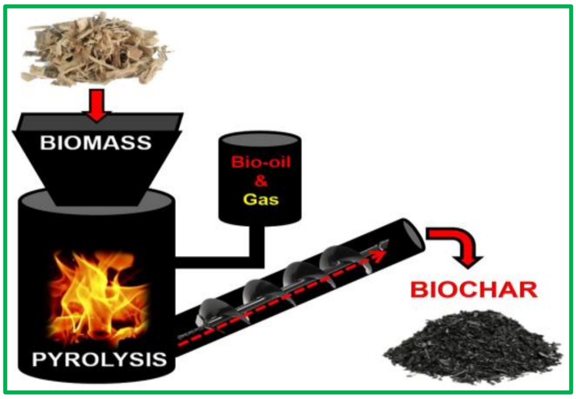
Process of Biochar Production

1. Pyrolysis: The process of pyrolysis involves heating biomass in the absence of oxygen to produce biochar as the primary byproduct. It is most commonly used method for biochar production. There are two types of pyrolysis i.e slow pyrolysis and fast pyrolysis.

a. Slow pyrolysis is the process in which biomass un-dergoes decomposition at a low heating rate (0.1°C-0.8°C/s) with sufficient residence time (>30 min).

b. In fast pyrolysis, biomass is heated at a higher rate (1000°C/s) with residence time < 2 seconds and is used to produce bio-oil and syngas as the main products.

2. Gasification: (700°C-1000°C) is a partial oxidation of biomass. The process yields byproducts such as biochar (mixed with tar and ashes) and syngas.



3. Torrefaction: (200°C-300°C) converts biomass in the absence of oxygen at a low heating rate (50°C/min) to produce bio-oils or biochar.
4. Flash carbonization: is a process that transforms bio-mass mostly into gaseous and solid products by igniting a flash fire under a packed bed of biomass at higher pressures (1 to 2 MPa) for less than half an hour.

Preparation of Biochar

There are different ways to make biochar with the heating of biomass with little or no oxygen to drive off volatile gasses, leaving carbon behind. Biochar can be produced at scales ranging from large industrial facilities down to the individual farm, making it applicable to a variety of socioeconomic situations. To make biochar technology popular among the farmers, it is imperative to develop low cost biochar kiln at community level or low cost biochar stove at individual farmer‘s family level. The various methods which are in vogue are as under:
1. *Heap Method*: It is one of the traditional practices where a heap of pyramid like structure (earth kiln) is prepared by keeping wood logs and roots of plants for making charcoal. To allow the combustion products to escape, vents are opened starting from the top and working downwards. When smoke production is stopped, the cooling process is started by covering stack with a layer of moist earth. The cooling process takes several days before the earth is removed and the biochar produced is separated from the surrounding carbonized portions.
2. *Drum Method*: Kilns that are built in place, typically are constructed from soil or other local materials, are located close to biomass resources and are small. They are economically viable if the cost of construction and transportation of biochar is lower than the cost of transporting and processing of biomass. A square shaped hole of 16 cm x 16 cm was made on the centre of top side of the drum for loading the crop residues. On the opposite side (bottom) of the oil drum, a total of 36 holes each measuring 4 cm^2 were made in concentric circles with a 5 cm^2 hole at the center covering 20% of the total surface area of the bottom portion of the oil drum to facilitate uniform circulation of air from below.
3. *Biochar Stove*: New stove technologies can produce both heat for cooking and biochar for carbon sequestration and soil building. Limited testing indicates that these stoves are much more efficient and emit less gas. Biomass fuel is placed between the two cylinders and a fire is ignited in the centre. Heat from the central fire pyrolyzes the concentric ring of fuel. The gases escape to the centre where they add to the cooking flame as the ring of biomass turns to char. The key aims of the design are to reduce the indoor air pollution that results from cooking and to take advantage of the abundance of bio-residues found in rural areas in developing countries.

Methods of application: 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. In developed countries, several large scale biochar trials have been conducted using a tractor propelled lime spreader.
Rate of application: It depends on many factors including the type of biomass used, the degree of metal contamination in the biomass, the types and proportions of various nutrients (N, P, etc.). Application to soils of higher amounts of biochar may increase the carbon credit benefit; but, in nitrogen-limiting soils it could fail to assist crop productivity as a high C/N ratio leads to low N availability. The most suitable application rate of biochar was 10.1−20 t/ha or 2.01–4 %.
Soil quality and fertility improvement: Biochar can act as a soil conditioner by improving the physical and biological properties of soils such as water holding capacity and soil nutrients retention, and also enhancing plant growth. The application of biochar in soils is based on its properties such as:

(i) Agricultural value from enhanced soils nutrient retention and water holding capacity
(ii) Permanent carbon sequestration
(iii) Reduced GHG emissions, particularly nitrous oxide (N_2O) and methane (CH_4) release.
(iv) Increase soil pH
(v) Decrease aluminum toxicity
(vi) Decrease soil tensile strength
(vii) Improve soil conditions for earthworm populations
(viii) Improve fertilizer use efficiency

Biochar for climate change mitigation

***Carbon sequestration**:* Soil Carbon sequestration is the removal of atmospheric CO_2 through photosynthesis to form organic matter, which is ultimately stored in the soil as long-lived, stable forms of C

***Biochar limits N availability in soil**:* Biochar to support microbial growth and activity and may induce N immobilization in soil as the microorganisms utilize C from the volatile or labile components within biochar.

Bioavailable C in biochar is oxidized by N_2O: A range of aromatic and aliphatic compounds are oxidized by N_2O. Biochar contains a range of aromatic and non-aromatic compounds on their internal and external surfaces, resulting in the reduction of N2O.

***Biochar increases soil pH**:* Biochar can be alkaline and the extent of alkalinity varies depending on feedstock type and pyrolysis temperature. Thus, biochar possessing significant alkalinity can be used to ameliorate acidity and increase soil pH.

Biochar affects gas diffusivity and aeration: Soil structure, in particular porosity and pore architecture, regulates movement and storage of water and gas into and within soil. Biochar can increase soil porosity directly by reducing bulk density. The increase in soil aeration as a function of biochar type and application rate reduces anaerobic micro-sites and consequently may result in decreases in N_2O emissions by minimizing denitrification.

Conclusion

Climate change is one of the burning issues of 21st century, not only have a detrimental effect on the animal kingdom but also plant kingdom is worst victim of it. Biochar is one such strategy which can act as a revolutionary tool in mitigating the climatic change. The escape of greenhouse gases *viz* CO_2, CH_4 and N_2O into the atmosphere can be curtailed by incorporating biochar into the soil. It not only traps the carbon into the soil by the process of carbon sequestration but also minimizes the production of methane gas from marshy and inundated soils like paddy fields. Besides the above mentioned facts, it also improves the physical, chemical and biological properties of soil and also its production and application does not require too much expertise and even a lay man can practice it at ground level.