Agri Articles
(e-Magazine for Agricultural Articles)
Volume: 06, Issue: 01 (JAN-FEB, 2026)
Available online at http://www.agriarticles.com

Biochar: Importance in Climate Change Mitigation and Agriculture

*Meenal Dubey[1] and Shashikala Lakra[2]
[1]College of Agriculture and Research Station, Raigarh, IGKV, Raipur, (C.G.)
[2]College of Horticulture and Research Station, Kunkuri, MGUVV, Durg, (C.G.)
*Corresponding Author's email: dubeymeenal27@gmail.com

Agriculture has two significant challenges: sustainable agricultural production and climate change. Biochar has been strongly recommended as a potential agricultural management tool to address the conflict between crop yield and greenhouse gas emissions. In order to create a sustainable economic system, all waste must be eliminated or recycled into new, useful products. But trash can take many different forms, and since there is no one-size-fits-all answer, managing waste effectively requires a variety of approaches. Biochar has been strongly recommended as a potential agricultural management tool to address the conflict between crop yield and greenhouse gas emissions. Policymakers and scientists stress the significance of comprehending organic waste, especially its sustainability issues, in relation to biochar. Waste biomass can be kept in circulation using a variety of methods and technologies rather than being sent to landfills or conventional treatment facilities, which degrade ecosystems and resources. Biochar is defined as charcoal and carbon-rich material produced by partial oxidation (pyrolysis at ≤700 °C in the absence or limited supply of oxygen) of carbonaceous organic sources such as wood and plants, excluding fossil fuel products. Biochar is an economical and effective biomaterial that has several biological qualities, including environmental sustainability, non-cytotoxicity, and biocompatibility.

How Biochar is made

In carefully regulated conditions, organic waste can be transformed into energy or new types of material. The characteristics of biomass can be changed by altering the temperature, air pressure, or oxygen content, producing solid materials with new characteristics as well as liquid and gas fuels. The following is a list of the main kinds of thermochemical conversion.
Combustion,
Pyrolysis,
Gasification,
Torrefaction and
Hydrothermal carbonization
Different amounts of oxygen are needed for each process to take place. When there is none, pyrolysis takes place. There is a finite amount in gasification, yet combustion cannot occur without it.

Importance in Climate Change Mitigation and Agriculture

a. Carbon sequestration potential: Carbon dioxide (CO_2) from the atmosphere is captured and stored in a stable reservoir as part of the carbon sequestration process. A passive reservoir of stable carbon must be established in order to successfully lower atmospheric carbon. Unlike the modest retention rates of 3% after burning and 10–20% after decomposition after several years, bio-char helps this transition by maintaining about 50% of the initial carbon content.

b. Reduction of GHG: A major contributor to greenhouse gas emissions is the burning of crop residue; burning paddy straw releases the most CO_2 (70%), CO (7%), CH_4 (0.66%), and N_2O (2.09%). On the other hand, carbon sequestration and a decrease in non-CO_2 greenhouse gasses are two advantages that biochar provides for the environment. It encourages soil nitrogen immobilization, which reduces N_2O emissions. Biochar is thought to have the potential to cut India's 1,900 million tons of CO_2 emissions in 2009 by two to four percent.

c. Role of Biochar in Soil Improvement

i. **Soil fertility enhancement:** It is often believed that biochar works well as a soil amendment in a variety of soil types. Scientist have found in their research that it increases plant development by enhancing the fertility and physico-chemical characteristics of the soil, in order to increase root activity, biochar can enhance root-soil interactions in specific root-soil zones It alters the nutritional and microbial composition. Improved soil fertility and structure are directly linked to increased crop yields and more effective use of water and nutrients.

ii. **Nutrient retention and slow-release properties**: Both the increased nutrient retention and the reduced leaching of applied fertilizers out of the soil–plant ecosystem can be attributed to biochar-amended soils' improved water-holding capacity and increased cation and anion exchange capabilities.

iii. **Soil structure and aggregation:** Many scientists have also found that it may improve soil aggregation, porosity, and water-holding capacity (WHC) while decreasing bulk density, it may find utility in long-term adaption applications.

iv. **Impact on soil pH and microbes:** Being alkaline, biochar has the ability to raise soil pH, which is important for influencing microbial populations and the virulence of pathogens. It has the ability to affect soil life, including fungi, bacteria, and other microbes. According to research, the amount and variety of these microorganisms in the soil frequently increase when biochar is applied. This occurs because biochar changes pH, releases nutrients and organic substances that are favorable to microbes, and creates pores for shelter.

v. **Remediating soils by removal of heavy metals:** Biochar serves as an effective alternative for remediating soils contaminated by heavy metals, thanks to its high surface area, cation exchange capacity, and functional groups that immobilize contaminants. Its efficacy is influenced by the type of biomass used and pyrolysis temperature during production. This application is crucial for restoring areas affected by mining or excessive pesticide use, improving soil quality and aiding in carbon sequestration, which contributes to climate change mitigation.

d. **Crop yield improvement:** A number of experiments have been conducted worldwide to thoroughly examine how biochar amendments affect plant growth, especially agricultural yield. It has been found that adding biochar to agricultural soils can greatly increase crop output by raising both shoot biomass and grain production.

e. **Use in organic farming:** Depending on the production process and environmental factors, biochar improves soil characteristics such as bulk density, surface area, porosity, and moisture content. In addition to increasing mycorrhizal abundance, nitrogen fixation, and microbial biomass, it also raises soil pH, organic carbon, and cation exchange capacity. Application of biochar thereby improves nutrient availability and retention, promoting improved crop yields and plant growth. It is suitable for use in organic farming due to all of these characteristics.

f. **Livestock manure management:** The incorporation of this substance into animal feed has the potential to decrease methane emissions and boost productivity in animals. According to research performed by Professor Yosra Soltan of Alexandria University, adding biochar to animal feed can lower methane (CH_4), a key greenhouse gas from cattle. Her study showed a 12% increase in milk output and a 20% reduction in methane emissions.

g. **Biochar-based fertilizers:** Fertilizers made from biochar, which is made from agricultural waste, are a potential development in present-day farming. They lower greenhouse gas emissions, improve nutrient dynamics, and increase soil quality. Higher crop yields are supported by changes in soil structure and nutrient efficiency. These fertilizers also promote sustainable resource recycling while reducing emissions of nitrous oxide and methane. However, issues like excessive manufacturing costs and variations in efficacy among soil types continue to exist.

h. **Biochar and compost:** According to some research, the advantages of including biochar into the composting process could include less odor, shorter compost periods, lower rates of greenhouse gas emissions (methane, CH4, and nitrous oxide, N2O), decreased ammonia (NH3) losses, and the capacity to act as a bulking agent for compost.

How to apply Biochar

Biochar can be applied to soil using various methods, including band placement, topsoil mixing, top dressing, and planting holes. It can be spread directly or mixed with seed, compost, manure, and crop residue. Popular techniques include surface application in established crop areas and banding, which involves adding biochar 10–20 cm below the soil surface to improve its interaction with plants while minimizing dust.

Limitations

- **High Cost:** Due to the requirement for specialized machinery and energy, producing biochar can be expensive, making it difficult for farmers in developing countries to access. These expenses are being lowered, though, by developments in local manufacture from waste materials and small-scale pyrolysis plants.
- **High pH:** It can improve soil pH and help crops in acidic soils since biochar made from woody biomass at high temperatures (over 500 °C) is usually quite alkaline, with a pH above eight. In already alkaline soils, it could worsen nutrient imbalances and salinization, resulting in pH levels that are inappropriate for certain crops and adversely influencing crop development and nutrient availability.
- **Adding Pollutants to Soil:** When contaminated feedstocks, like those from railroad earthworks or dirty soil, are used to generate biochar, contaminants may enter the soil, raising its pH significantly and/or inhibiting plants' ability to absorb minerals.
- **Less knowledge and awareness:** The advantages of biochar and how it might be used into farming methods are often unknown to farmers. To help farmers understand the benefits and real-world applications of biochar in organic farming, it is essential to improve education, extension services, and case studies.
- **Health Risk:** Dust is the biggest health hazard associated with biochar and the most difficult aspect of applying it in the field. Tiny pieces of char can irritate and damage the lungs when they are inhaled.

Conclusion

Biochar has been shown to enhance the properties of soil, including increasing nutrient availability and pH, as well as encouraging improved plant growth and yield. Because of its porous nature, it can boost the microbial population, which could benefit crop productivity. The biggest utilization of biochar is in climate change mitigation by reducing the reducing greenhouse gas emissions and sequestering carbon. However, there have also been some detrimental effects of biochar discovered, and long-term studies have shown the reverse effect on crop productivity and soil health. Extension services and public funds are needed to do additional study on the topic in order to close the knowledge gap and raise awareness among farmers and other stakeholders.