BIOCHAR: AN ENVIRONMENT FRIENDLY TOOL FOR ENHANCING SOIL HEALTH AND CROP YIELD

YASHWANT GEHLOT[1]*, BRIJLAL LAKARIA[2], M VASSANDA COUMAR [3], BHARTI PARMAR[1]

[1]College of Agriculture (Rajmata Vijayaraje Scindia Krishi Vishwavidyalaya), Gwalior, Madhya Pradesh, India; [2]ICAR-Indian Institute of Soil and Water Conservation, RC, Chandigarh, India; [3]ICAR-Indian Institute Soil Science, Bhopal, Madhya Pradesh, India

*Corresponding Author, E-mail: yashagarmalwa51@gmail.com

Biochar is a carbon-rich organic material, a by-product of the pyrolysis of biomass under high temperature and low oxygen (Panwar et al., 2019). This production process is referred as 'slow pyrolysis' i.e., heating of biomass (like wood, manure, or leaves) in the presence of little or no oxygen. Biochar has high content of stable carbon hence; its application in soil has many benefits such as improving soil health and protecting the environment. Due to its high surface area, porosity, and stability, biochar has the potential to alter soil properties in a profound manner like enhancement of the physical properties, nutrient retention and microbial activities. Various benefits associated with biochar in improving health of agricultural soils make this soil amendment a promising component of restoring agricultural systems with degraded lands. Role of biochar in carbon storage, reduction of emissions, and controlling pollution make it an essential part of the environmental management solutions and climate change mitigation strategies.

This article examines the significance of biochar in soil health management, improving crop production and maintaining the environment less polluted and healthy, highlighting the potential of this low-cost carbon source as a tool in managing soil and agricultural systems.

IMPACT OF BIOCHAR ON SOIL HEALTH

Use of biochar in soil have several direct and indirect benefits to enhance the health of degraded or degrading soils (Figue 1). Some of them are explained below:

Enhancing the Soil Organic Carbon Content:

Biochar application offers the primary benefit of boosting the soil organic carbon (SOC) level since its integration with land management practices offers a stable carbon reservoir in the soil. A field experiment conducted at ICAR-IISS Bhopal in rice-wheat system during 2021-2023 revealed a significant increase in the SOC content with the application of biochar as illustrated in Figure 2. This is mainly due to the highly porous structure of biochar which provides a conducive environment for the growth of beneficial microorganisms that aids in retaining soil organic matter, thereby locking carbon in the soil by preventing its release into the atmosphere.

Improving Soil Structure: Impact of biochar on the physical properties of soil chiefly due to improvement in porosity and aggregate stability. Improved soil aeration and less compaction promotes better root growth, more water infiltration and less erosion, that eventually build a resilient agroecosystem.

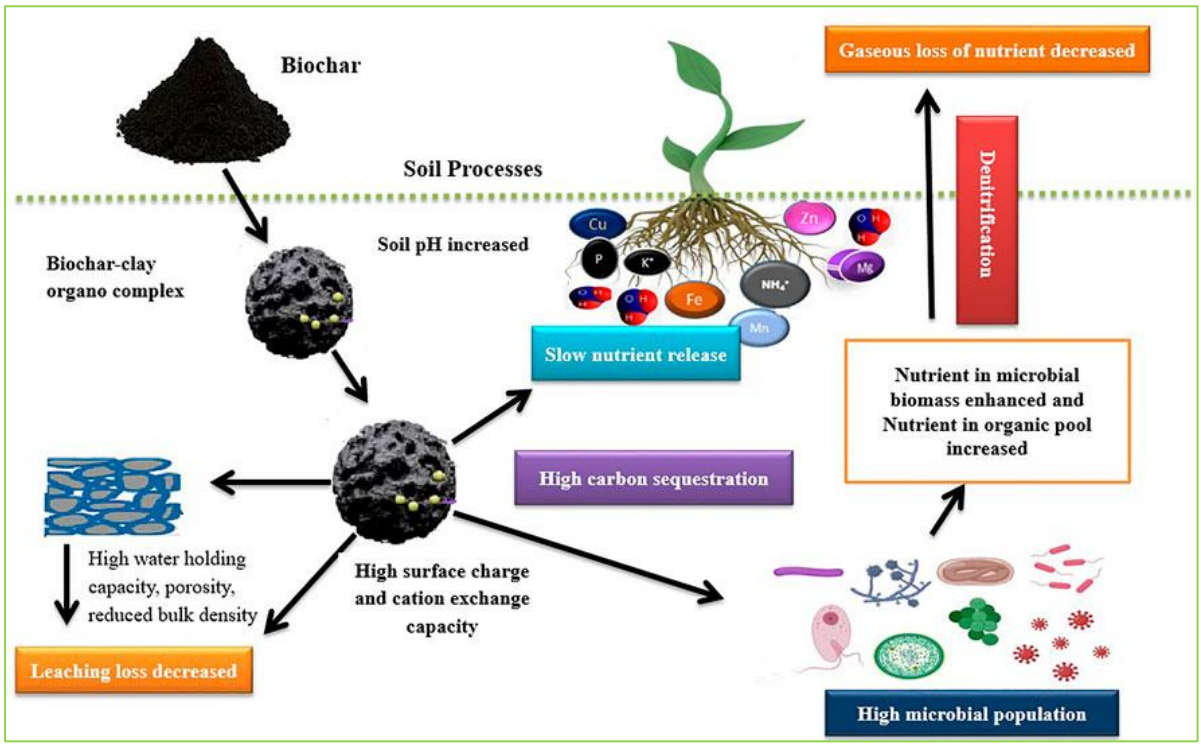

Figure 1. Impact of biochar on soil properties and plant growth (Source: adapted from Murtaza et al, 2023)

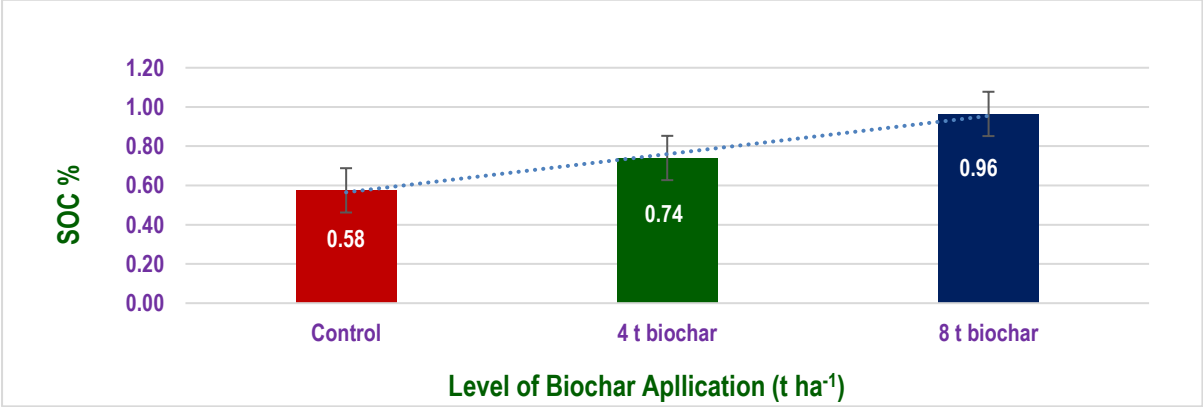

Figure 2. Effect of biochar on the soil organic carbon (SOC) level in the Vertisol of Bhopal, Madhya Pradesh

Enhancing Nutrient Availability: Biochar has a high surface area and negative charge which helps to absorb and retain essential nutrients such as nitrogen, phosphorus and potassium (Liu et al, 2018). Hence, soils incorporated with biochar possess the ability to store nutrients for longer time period, reducing the need for frequent application of chemical fertilizers. Improved availability of nutrients promotes healthy plant growth.

Boosting Water Retention: The ability of biochar to hold moisture in its porous structure improves the water holding capacity of soils that helps to reduce the frequency of irrigation required for crops. This would be beneficial particularly for crops grown in the drought prone regions.

Enhancing Soil Microbial Activity: Beneficial soil microbes like fungus and bacteria can live in biochar. These microbes are essential to the breakdown of organic materials, cycling of nutrients, and health of plants. In order to maintain overall soil fertility and ecosystem functioning, biochar encourages microbial activity, which in turn helps maintain a healthy and diversified soil microbiome.

IMPACT OF BIOCHAR ON CROP YIELD

Effects of biochar on crop yield mostly depend on the quantity applied and soil type. Biochar application is reportedly more effective in soils with low to medium fertility level. A field study conducted in the vertisols of ICAR-IISS Bhopal revealed the positive effect of biochar on crop yield. There was a yield enhancement of about 10% in rice crop with biochar when applied along with NPK fertilizers and farmyard manure (FYM) compared to that of only NPK and FYM applied plots. Study of Liu et al. (2017) that compared data of biochar use in agriculture from 59 pot experiments and 57 field experiments across 21 countries revealed an average increase of 11% in crop productivity with biochar.

ENVIRONMENTAL IMPACT OF BIOCHAR

The positive impacts of biochar on environment includes improved soil health and reduced emission of carbon dioxide (CO_2) from soils. The enhanced soil carbon storage has a direct positive impact on mitigating the climate change effects on agriculture as well as human health. Besides, application of biochar helps to reduce the emission of nitrous oxide (N_2O) from acidic soils, particularly if the biochar is produced using poultry manure and green waste (Brtnicky et al, 2021). It has been also reported that methane (CH_4) emissions from agricultural soils can be reduced with biochar application since in soil, biochar enhances the methanotroph pmoA gene and suppresses methanogenic archaea which are essential in the reduction of methane (Wang et al, 2018). Moreover, certain types of biochar when incorporated in the diet of cattle, who are known as one of the biggest sources of methane emissions, lower the emission of methane by ruminant animals (Rajpoot et al, 2024).

METHODS OF BIOCHAR APPLICATION

Like any other soil organic amendments biochar can be applied to the soil in a wide variety of ways such as broadcasting, band application, spot placement, deep banding etc. The mode of application is connected with a variety of factors like the reason of biochar used, type of farming system, availability of machinery and labour etc. For example, to improve soil fertility, biochar should be applied at the soil surface or in the root zone where most of the nutrient cycling and plant uptake occur (Figure 3.). If biochar is to be used only for soil carbon sequestration, then it needs to be incorporated in the deeper layers of soil. While using biochar in agriculture, it is necessary to take account of the cropping system.

Biochar can be blended with composts and manures to minimize the odour and enhance nutrient availability in soil for long duration. To have uniform distribution in the topsoil, biochar may be broadcasted or side dressed in tree plantations without turning the soil.

Figure 3. A view of the ICAR-IISS experimental fields Applied with Biochar before transplanting rice crop

Studies shows that biochar amendment to crops in various soils and crops can be at a rate of 5-20 t ha^{-1} depending up on the type of soil, crops and cropping sequence etc. Further, blending of biochar with other organic amendments like FYM, compost, slurry and vermicompost may enhance the efficacy of biochar.

CONCLUSION

Global research conveys that biochar is an important tool to check the potential threat of climate change by eliminating the greenhouse gas emissions associated with various agriculture practices to a greater extent. The potential of biochar to improve soil health and crop productivity along with a slight saving on irrigation water and chemical fertilizers offers a big opportunity for farmers to integrate this eco-friendly agricultural input with their farming system. Although benefits of biochar application in soil were reported by many researchers across the globe use of this carbon-rich material is not that much popular among farmers particularly in countries like India. Factors behind the unpopularity of biochar may be many like farmers' lack of awareness about the benefits of biochar, its local unavailability, or even farmers' resistance to adopt new technologies. Considering the value of biochar in carbon storage and its role in climate change mitigation more efforts are required from various government as well as private agencies engaged with popularisation of eco-friendly agricultural technologies.

REFERENCES

Brtnicky, M., Datta, R., Holatko, J., Bielska, L., Gusiatin, Z.M., Kucerik, J., Hammerschmiedt, T., Danish, S., Radziemska, M., Mravcova, L. and Fahad, S., 2021. A critical review of the possible adverse effects of biochar in the soil environment. Science of the Total Environment, 796, p.148756.

Kabir E, Kim K-H and Kwon EE (2023), Biochar as a tool for the improvement of soil and environment. Front. Environ. Sci. 11:1324533. doi: 10.3389/fenvs.2023.1324533.

Lakaria BL, Jha P, Biswas AK, Patra AK and Chaudhari SK (2021) Protocol for Biochar Use in Indian Agriculture. ICAR- Indian Institute of Soil Science Bhopal, MP,13p.

Liu, L., Tan, Z., Gong, H., & Huang, Q. (2018). Migration and transformation mechanisms of nutrient elements (N, P, K) within biochar in straw–biochar–soil–plant systems: a review. ACS Sustainable Chemistry & Engineering, 7(1), 22-32.

Murtaza, G., Ahmed, Z., Eldin, S.M., Ali, B., Bawazeer, S., Usman, M., Iqbal, R., Neupane, D., Ullah, A., Khan, A., Hassan, M.U., Ali, I. and Tariq, A. 2023. Biochar-Soil-Plant interactions: A cross talk for sustainable agriculture under changing climate. *Frontiers in Environmental Sciences*. 11:1059449

Panwar, N. L., Pawar, A., & Salvi, B. L. (2019). Comprehensive review on production and utilization of biochar. SN Applied Sciences, 1, 1-19.

Rajpoot, S.K., Sharma, P.R., Singh, J., Kumar, A., Vijayakumar, S., Chaudhary, R. and Kumar, D., 2024. Biochar as a novel feed additive for ruminants. In Feed Additives and Supplements for Ruminants (pp. 423-435). Singapore: Springer Nature Singapore.

Wang, Y.Q., Bai, R., Di, H.J., Mo, L.Y., Han, B., Zhang, L.M. and He, J.Z., 2018. Differentiated mechanisms of biochar mitigating straw-induced greenhouse gas emissions in two contrasting paddy soils. Frontiers in microbiology, 9, p.2566.

***

Article received on: 19 September, 2024