

Biochar: A Sustainable Black Gold for Climate-Resilient Agriculture

K. Rajesh*, N. Sainath, P. Ravi, Y. Swathi, K. Ramakrishna and CH. Venureddy

*Regional Agricultural Research Station, Jagtial 505 529
Professor Jayashankar Telangana Agricultural University, Telangana, India*

Corresponding Author

K Rajesh

Email: kunta.rajesh3@gmail.com



OPEN ACCESS

Keywords

Biochar, Properties, Soil quality, Fertility improvement

How to cite this article:

Rajesh, K., Sainath, N., Ravi, P., Swathi, Y., Ramakrishna, K. and Venureddy, C. H. 2026. Biochar: A Sustainable Black Gold for Climate-Resilient Agriculture. *Vigyan Varta* 7 (06): 186-189.

ABSTRACT

Biochar is a carbon-rich, porous material produced through the pyrolysis of biomass under limited oxygen conditions. It offers a sustainable solution for converting agricultural residues and organic wastes into valuable resources while reducing environmental pollution caused by residue burning. Due to its high surface area, porosity, and stable carbon structure, biochar improves soil physical, chemical, and biological properties by enhancing water retention, nutrient availability, soil aeration, and microbial activity. Its application has been shown to increase fertilizer use efficiency, improve crop productivity, and enhance soil fertility, particularly in degraded and infertile soils. Biochar also plays a significant role in environmental remediation by adsorbing pollutants and heavy metals. Furthermore, it serves as an effective carbon sequestration tool, reducing greenhouse gas emissions and contributing to climate change mitigation. Owing to its multiple agronomic and environmental benefits, biochar is increasingly recognized as a key component of sustainable and climate-resilient agriculture.

INTRODUCTION

Agricultural waste is often treated as a liability because effective methods to convert it into valuable assets are

lacking. As a result, crop residues especially rice and wheat straw among cereals are either underutilized or completely unused. The

easiest way for farmers to clear fields is often burning these residues, which releases large volumes of smoke and greenhouse gases. Recognizing these challenges, researchers have developed biochar, a highly stable form of organic matter. Biochar significantly improves soil fertility and acts as a powerful soil amendment, boosting crop yields and plant growth more effectively than traditional organic materials like leaf litter, compost, or manure. Converting biowaste into biochar also offers a promising strategy for carbon sequestration and reducing greenhouse gas emissions (Chan *et al.*, 2007).

What is biochar

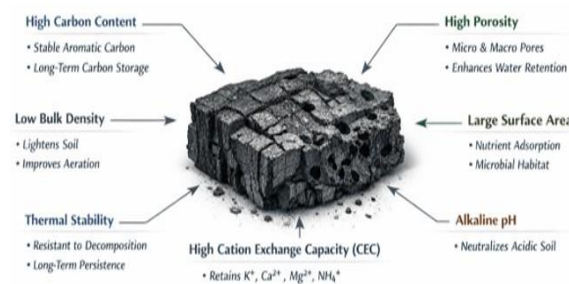
Biochar is a fine-grained, carbon-rich, porous material produced when plant biomass undergoes thermo-chemical conversion (pyrolysis) at high temperatures in the presence of little or no oxygen.

Its most valuable characteristic as a soil amendment is its highly porous structure, which:

- Increases soil surface area
- Enhances water retention
- Improves nutrient holding capacity

Due to its aromatic carbon-dominated structure, biochar is biochemically recalcitrant meaning it resists decomposition far better than uncharred biomass. This allows it to:

- Build long-term soil carbon pools
- Achieve a net carbon withdrawal of ~20% from the atmosphere



Biochar properties

Biochar production

Biochar is produced by heating biomass in the total or partial absence of oxygen. Pyrolysis is the most common technology employed to produce biochar, and also occurs in the early stages of the combustion and gasification processes. Besides biochar, bio-oil and gas can be collected from modern pyrolyzers. These could be refined to a range of chemicals and/or used as sources of renewable energy if derived from sustainably produced biomass.

Soil quality and fertility improvement

Biochar's porous structure increases soil surface area and water retention, while its stable aromatic carbon enhances long-term soil carbon storage.

When applied to soil, biochar interacts with:

- The soil matrix (texture, structure, porosity)
- Soil microbes (fungi, bacteria)
- Plant roots (penetration, nutrient access)

These interactions depend on:

- Biomass and biochar composition
- Production method and temperature
- Biochar physical properties
- Soil conditions (temperature, moisture)

In infertile soils, biochar:

- Decreases bulk density
- Increases pore volume and water-holding capacity
- Improves texture, structure, and aeration
- Enhances root-zone availability of air and water

Table 1. Effect of biochar on different soil properties

S. No.	Particular	Impact
1	Cation exchange capacity	50 % increase
2	Bulk density	13 % decrease
3	Water holding capacity	5.9 to 25.5% increase
4	Total pore volume	16 % increase
5	Specific surface area	15 % increase
6	Fertilizer use efficiency	10 to 30 % increase
7	Liming agent	01point pH increase
8	Methane emission	100 % decrease
9	Nitrous oxide emissions	50 % decrease
10	Mycorrhizal fungi	40 % increase
11	Biological nitrogen fixation	50 to 72 % increase

Environmental Remediation

Carbonaceous materials like biochar and activated carbon are increasingly used to:

- Sequester heavy metal contaminants
- Release essential nutrients like sulfur

Biochar's structured carbon matrix and medium-to-high surface area allow it to act as a surface sorbent, similar to activated carbon, binding pollutants while improving soil health. However, more research is needed on how aging affects biochar's integrity for long-term agricultural and environmental remediation.

Crop productivity

The application of biochar to soil has been shown to improve crop yields which could be due to direct or indirect effects. The direct effect is explained by the fact that biochar being concentrated during pyrolysis contains higher amount of nutrients than the biomass from which they are prepared. The indirect effect is due to improvement in soil physical, chemical and biological properties due to biochar application. Several workers have reported that biochar applications to soils have shown positive responses for net primary crop

production, grain yield and dry matter (Nagual *et al.*, 2017). Several workers have reported that biochar applications to soils have shown positive responses for net primary crop production, grain yield and dry matter.



Sequestering biochar in soil, which makes soil darker in colour is a robust way to store carbon

Biochar for greenhouse gas mitigation

As one major goal of biochar soil amendment is to sequester carbon in order to mitigate climate change, numerous studies addressed the microbial response to biochar addition in terms of emissions of the greenhouse gases N₂O, CO₂ and CH₄ from soil. In comparison to burning, controlled carbonization converts even larger quantities of biomass organic matter into stable C pools. The conversion of biomass carbon to biochar leads to sequestration of about 50% of the initial carbon compared to the low amounts retained after burning (3%) and biological decomposition. Biochar is added sustainably, per annually sequester an amount of C equal to 12% the current anthropogenic CO₂ emissions. It was reported to reduce N₂O emission could be due to inhibition of either stage of nitrification and/or inhibition of denitrification, or promotion of the reduction of N₂O, and these impacts could occur simultaneously in a soil.

CONCLUSION

Biochar represents a transformative solution for:

- Converting agricultural waste into valuable assets

- Enhancing soil fertility and crop productivity
- Sequestering carbon and mitigating climate change
- Remediating contaminated soils

As "the new black gold," biochar offers a sustainable pathway toward regenerative agriculture and climate-resilient farming systems.

REFERENCES

Chan KY, Van Zwieten L, Meszaros I, Downie A, Joseph S. Agronomic values of greenwaste biochar as a soil amendment. *Aus. J. Soil Res.* 2007; 45: 629-634.

Nagula S, Usha PB, Thampatti KM. Evaluation of chemical characteristics of biochar synthesized pyrolytically from lignocellulose biomass. *Trends Biosci.* 2017; 10(27): 5695-5699.