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Role of Biochar in Enhancing Greengram Productivity: A Sustainable Approach for Improving Soil Health and Crop Yield

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Greengram (*Vigna radiata* L.), commonly known as mungbean, is an important short-duration pulse crop and an integral part of sustainable farming systems. It is valued not only for its nutritional importance but also for its ability to contribute to soil fertility through biological nitrogen fixation. However, greengram productivity is often restricted by declining soil organic matter, poor nutrient availability, inadequate moisture, and deterioration of soil physical and biological properties. In this situation, improving soil health along with crop productivity has become increasingly important. Biochar has attracted considerable attention as a potential soil amendment because of its unique physical and chemical characteristics. It is a carbon-rich material obtained by heating biomass under limited oxygen conditions. Agricultural residues such as crop straw, rice husk, sugarcane residues, and other plant materials can be converted into biochar, providing an opportunity to utilize farm wastes while returning stable carbon to the soil. Depending on its feedstock and production conditions, biochar can improve soil structure, water retention, nutrient-holding capacity, microbial activity, and carbon storage. Recent research has also demonstrated encouraging responses of mungbean to biochar application, including improvements in nodulation, yield attributes, grain yield and grain nitrogen concentration. However, the response is not uniform and depends on biochar type, application rate, soil characteristics, climatic conditions and nutrient management. Therefore, biochar should not be considered simply as a replacement for fertilizers, but rather as a soil-conditioning component of integrated nutrient management. This article discusses the production and properties of biochar, its mechanisms of action in soil, its influence on greengram growth and yield, its interaction with biofertilizers and fertilizers, and its potential role in climate-smart agriculture. The article also highlights the major limitations and research gaps that need attention before large-scale adoption of biochar in greengram production.

Keywords: Biochar, Vigna radiata, greengram, mungbean, soil health, nutrient use efficiency, biofertilizer, sustainable agriculture, carbon sequestration

Introduction

Greengram is one of those crops that quietly contributes a lot to Indian agriculture. It is a short-duration pulse, fits well into different cropping systems and provides an affordable source of dietary protein. Its ability to fix atmospheric nitrogen through symbiosis with Rhizobium also makes it particularly useful from the soil fertility point of view. However, good crop potential does not always translate into good yield. In many agricultural soils, continuous cultivation, low addition of organic matter, imbalanced fertilizer use and poor moisture availability gradually reduce soil quality. For a crop like greengram, which has a relatively short growing period, any limitation in nutrient or water availability during the critical stages of growth can directly affect flowering, pod formation and final seed yield.

Biochar has emerged as one such option. It is not a conventional fertilizer. Rather, it is a stable carbon-rich material that can modify the soil environment and influence the availability and movement of water and nutrients. Its porous structure can provide space for microorganisms, while its surface can retain nutrients and other compounds. Research across different cropping systems indicates that the effect of biochar is strongly influenced by soil type, feedstock, pyrolysis conditions, application rate and accompanying nutrient management. A recent meta-analysis also reported that biochar can have positive effects on soil carbon and crop productivity, with stronger responses in low-fertility and acidic soils and when biochar is combined with suitable nitrogen management.

Biochar: Production and Basic Properties

Biochar is produced by thermally decomposing biomass under conditions where oxygen is absent or severely limited. This process is generally known as pyrolysis. Depending on the feedstock and production conditions, different types of biochar with different properties can be produced. Crop residues, wood residues, rice husk, sugarcane bagasse and other agricultural wastes can serve as feedstocks. This makes biochar particularly interesting for agriculture because materials that are otherwise treated as waste can be converted into a useful soil amendment. The properties of biochar are not the same in every situation. Temperature, duration of pyrolysis, feedstock composition and production method influence its pH, surface area, porosity, ash content, nutrient concentration and stability. Therefore, two biochars produced from different materials cannot necessarily be expected to behave in the same way. The porous nature of biochar is one of its most important characteristics. Its internal pores provide a large surface area where water, nutrients and microorganisms can interact. Its relatively stable carbon structure also allows a portion of the carbon to remain in soil for long period.

Work of Biochar in Soil

A simple way to understand its action is to think of biochar as a small but highly active structure within the soil. Its pores can hold water and provide shelter for microorganisms, while its surface can retain nutrients.

Improvement in soil structure -Biochar can influence soil aggregation, porosity and bulk density. These changes may improve root penetration and create a more favourable environment for root growth.

Better nutrient retention -Because of its surface characteristics and, in some cases, increased cation exchange capacity, biochar can retain nutrients and reduce their movement away from the root zone. This is particularly useful in soils where nutrient losses through leaching are high.

Improved moisture availability- The pores present in biochar can retain water, although the magnitude of this effect varies with biochar characteristics and soil texture. Better moisture retention can become particularly valuable during short periods of rainfall deficiency.

Stimulation of microbial activity- Biochar can alter the habitat available to microorganisms and influence microbial biomass and nutrient cycling. A meta-analysis covering thousands of observations found positive effects of biochar on several microbial responses and nutrient-cycling functions.

Thus, the benefit of biochar does not come from a single mechanism. It is the combined effect of several changes taking place in the soil environment.

Role of Biochar in Greengram Growth and Yield

Jalal et al. (2024) evaluated biochar rates of 0, 10, 20 and 30 t ha^{-1} and reported improvements in several yield and quality attributes, with the highest treatment producing favourable responses in nodulation, pods $plant^{-1}$, biological yield, grain yield and grain nitrogen concentration. Another field experiment conducted in Pakistan also reported significant effects of biochar on soil organic matter, soil nitrogen, plant nitrogen, yield and biomass of mungbean. These findings are encouraging, but the results should not be converted into a universal recommendation of 30 or 40 t ha^{-1} for every greengram field. Such high rates may not be economically or agronomically appropriate under all conditions.

Biochar and Biological Nitrogen Fixation in Greengram

This is one of the most interesting aspects of biochar use in a pulse crop. Greengram has the ability to obtain part of its nitrogen requirement through biological nitrogen fixation. This process depends on effective interaction between the plant and compatible rhizobia. Healthy nodulation is therefore important for maintaining crop nitrogen supply. Biochar can influence the rhizosphere—the narrow zone of soil surrounding plant roots—by modifying moisture, pH, nutrient availability and microbial habitat. These changes can affect the survival and activity of beneficial microorganisms. Its porous structure may provide protected microsites where microorganisms can survive. This does not mean that biochar itself fixes nitrogen. Rather, it can potentially create conditions that favour the biological processes responsible for nutrient cycling. Research on mungbean has reported improvements in nodulation following biochar application. Jalal et al. (2024), for example, observed higher nodule density under biochar treatments. Therefore, the combination of biochar + effective Rhizobium inoculation deserves greater attention in greengram production.

Biochar in Integrated Nutrient Management

Biochar should not be viewed as a direct replacement for all fertilizers.This is a common misunderstanding that can lead to poor results. Biochar is primarily a soil amendment, whereas fertilizers are concentrated sources of plant nutrients. Their functions are different.The better approach is to integrate biochar with other nutrient-management practices. A practical integrated approach may include: Biochar + FYM/compost + recommended fertilizer + Rhizobium + PSB**.** Such combinations can address different aspects of soil fertility. Organic manure supplies decomposable organic matter and nutrients, biochar provides a relatively stable carbon framework, fertilizers supply readily available nutrients, and biofertilizers contribute to biological nutrient transformations. Research in other cropping systems has shown that combining biochar with organic amendments can improve soil quality and crop performance.

Limitations and Challenges

Although biochar has considerable potential, it is not a miracle input.

- One of the biggest challenges is variation in biochar quality. Biochar produced from rice husk will not necessarily behave in the same way as biochar produced from wood or sugarcane residues. Similarly, changes in pyrolysis temperature can alter its chemical and physical properties.

Other important challenges include:

- High initial cost
- Lack of standard recommendations
- Quality concerns
- Limited long-term field research
- Farmer awareness

Farmers need clear information regarding suitable feedstocks, application rates, methods and expected benefits. These limitations show why biochar should be introduced through scientific recommendations rather than simply promoted as a universal soil solution.

Research Gaps and Future Prospects

The research on biochar has expanded rapidly, but several questions remain unanswered, particularly for greengram under Indian field conditions. Future studies should focus on identifying the optimum biochar rate for different soil types rather than relying on a single recommended dose. Economic analysis is equally important. Farmers will adopt a technology only when the benefits justify the additional cost. Therefore, future studies should include:

- Cost of biochar production

- Transportation cost
- Labour requirement
- Net return
- Benefit:cost ratio
- Residual effect
- Carbon sequestration benefits

There is also considerable scope for developing low-cost, farm-level biochar production systems using locally available agricultural residues.

Conclusion

Greengram is an important pulse crop, but achieving higher and more stable productivity requires more than simply increasing fertilizer application. The condition of the soil has to be improved alongside crop nutrition. Biochar offers an interesting opportunity in this regard. By influencing soil structure, water retention, nutrient dynamics and microbial activity, it can create a more favourable environment for greengram growth. Its potential influence on nodulation and biological nitrogen fixation makes it particularly relevant to pulse-based production systems. Field studies on mungbean have already shown encouraging responses in yield, nodulation and grain quality, while broader research has demonstrated the potential of biochar to improve soil carbon, microbial functioning and crop productivity. However, biochar should not be treated as a universal fertilizer or applied at the same rate everywhere. Its performance depends on its source, production method, soil type, climate, application rate.

References

1. Jalal, F., Akhtar, K., Saeed, S., Said, F., Khan, Z. H., Hussain, S., Imtiaz, M., Khan, M. A., Liu, K., Harrison, M. T., Saud, S., Hassan, S., El-Kahtany, K., & Fahad, S. (2024). Biochar as sustainable input for nodulation, yield and quality of mung bean. Journal of Umm Al-Qura University for Applied Sciences, 10, 510–517. https://doi.org/10.1007/s43994-024-00121-5
2. Khan, S., Ismail, M., Ibrar, M., Haq, J. U., & Ali, Z. (2020). The effect of biochar on soil organic matter, total N in soil and plant, nodules, grain yield and biomass of mung bean. Soil and Environment, 39(1), 87–94. https://doi.org/10.25252/SE/2020/132088
3. Lehmann, J., & Joseph, S. (Eds.). (2015). Biochar for environmental management: Science, technology and implementation (2nd ed.). Routledge.
4. https://books.google.co.in/books?id=gWDABgAAQBAJ&pg=PA1&source=gbs_toc_r&cad=2#v=onepage&q&f=false
5. Majumder, S., Neogi, S., Dutta, T., Powel, M. A., & Banik, P. (2019). The impact of biochar on soil carbon sequestration: Meta-analytical approach to evaluating environmental and economic advantages. Journal of Environmental Management, 250, 109466. https://doi.org/10.1016/j.jenvman.2019.109466