International Journal of Plant & Soil Science

Volume 38, Issue 8, Page 773-780, 2026; Article no.IJPSS.164024
ISSN: 2320-7035

Yield and Economics of Indian Mustard (*Brassica juncea* L.) as Influenced by Biochar-based Nutrient Management under Gwalior Conditions

Harish Batham [a++*], Sachin Kumar Singh [a#], Hirdesh Kumar [a#], Arun Sahu [a#], Jay Prakash Thakur [a#], and Naveen Kumar Singh [b#]

[a] *School of Agriculture Science, Vikrant University, Gwalior, Madhya Pradesh, India.*
[b] *School of Natural and Applied Sciences, Vikrant University, Gwalior, Madhya Pradesh, India.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/ijpss/2026/v38i86258

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://pr.sdiarticle5.com/review-history/164024

Original Research Article

Received: 06/06/2026
Accepted: 06/08/2026
Published: 11/08/2026

Abstract

A field experiment was conducted during the *rabi* season of 2025-26 at the Agriculture Research and Development Centre, Sakatpura, School of Agriculture Science, Vikrant University, Gwalior, Madhya Pradesh, to evaluate the yield and economic responses of Indian mustard (*Brassica juncea* L.) to biochar-based nutrient management. The experiment was laid out in a randomised block design with eight treatments and three replications. The treatments comprised an absolute control, 100% of the recommended dose of fertilizer (RDF: 80:40:40:40 kg N:P_2O_5:K_2O:S ha^{-1}), and 100% or 75% RDF combined with mustard stover,

---

[++] *M.Sc. Agronomy Scholar;* [#] *Professor;*
**Corresponding author: E-mail: Jiharish093@gmail.com;*

Cite as: *Batham, H., Singh, S. K., Kumar, H., Sahu, A., Thakur, J. P., & Singh, N. K. (2026). Yield and Economics of Indian Mustard (Brassica juncea L.) as Influenced by Biochar-based Nutrient Management under Gwalior Conditions. International Journal of Plant & Soil Science, 38(8), 773–780. https://doi.org/10.9734/ijpss/2026/v38i86258*

Lantana camara, or wood/forest residue biochar @ 5.0 t ha^{-1}. The highest yield attributes were obtained with 100% RDF + *Lantana camara* biochar @ 5.0 t ha^{-1} (T_4), which recorded 340.00 siliquae $plant^{-1}$, 14.60 seeds $siliqua^{-1}$, and a 1,000-seed weight of 5.21 g. The same treatment produced the maximum seed yield (21.72 q ha^{-1}), stover yield (44.00 q ha^{-1}), biological yield (65.72 q ha^{-1}), gross returns (₹1,52,320 ha^{-1}), and net returns (₹1,03,720 ha^{-1}). However, 75% RDF + *Lantana camara* biochar @ 5.0 t ha^{-1} (T_7) recorded the highest benefit:cost ratio (3.14), with a comparable seed yield of 20.67 q ha^{-1}. The results indicated that integrating lantana biochar with fertilizer improved mustard productivity and profitability, while 75% RDF + lantana biochar may serve as a fertilizer-saving option where local biochar material is available.

Keywords: Biochar; benefit–cost ratio; fertilizer-use efficiency; Indian mustard; Lantana camara; net returns; nutrient management; recommended dose of fertilizer; seed yield; stover yield.

1. Introduction

Indian mustard (*Brassica juncea* L.) is an important *rabi* oilseed crop in India because it provides edible oil, protein-rich cake, stover, and a regular cash income for farming households. In semi-arid regions such as Gwalior, mustard productivity depends strongly on balanced nutrition, moisture conservation, and the efficient conversion of vegetative growth into reproductive yield. Nutrient limitations during branching, flowering, and siliqua development reduce the number of siliquae $plant^{-1}$, seed filling, test weight, and final seed yield. At the national scale, continued improvement in rapeseed–mustard productivity remains important because domestic edible-oil demand has outpaced supply, increasing the value of management practices that raise yield without proportionately increasing external inputs (Jat *et al*., 2019).

Biochar is a porous, carbon-rich soil amendment prepared by heating plant biomass under limited oxygen. Its agronomic value is associated with improvements in soil structure, nutrient retention, moisture availability, and microbial habitat (Glaser et al., 2002; Lehmann & Joseph, 2015). However, biochar is not a complete fertilizer substitute; more consistent responses are usually observed when biochar is integrated with mineral nutrients. Earlier studies have shown that responses to biochar vary with feedstock, soil type, and fertilizer level (Chan *et al*., 2007; Jeffery *et al.,* 2011; Ye *et al.,* 2020). Across diverse field conditions, quantitative syntheses indicate that crop responses to biochar are generally positive but are strongly moderated by soil pH, biochar properties, application rate, and accompanying nutrient inputs; consequently, site-specific integration with fertilizer is more defensible than assuming a uniform response (Biederman & Harpole, 2013; Liu *et al*., 2013; Schmidt *et al.,* 2021). Changes in bulk density, porosity, water retention, and nutrient availability provide plausible pathways for these responses, although their magnitude depends on soil texture and biochar production characteristics (Choudhary et al., 2022; Purakayastha et al., 2024; Sharma et al., 2021).

Recent field and synthesis studies further indicate that biochar performance depends on interactions among feedstock attributes, soil conditions, water management, and fertilizer supply, and that integrated applications can support crop productivity and resource-use efficiency under appropriate site conditions (Wang et al., 2023; Xiao et al., 2024; Xu et al., 2025).

Field evidence also shows that responses to biochar-based nutrient management vary with the amendment combination and crop context, including in systems that integrate biochar with organic or mineral nutrient sources (Essilfie et al., 2023; Dayoub et al., 2025).

Biochar source may be especially important in local nutrient management. Mustard stover biochar recycles crop residues, lantana biochar converts the invasive weed *Lantana camara* into a useful amendment, and wood/forest residue biochar provides a relatively stable, carbon-rich material. The present study focused on yield attributes, yield, and economics to determine whether biochar integration can improve mustard productivity and whether 75% RDF with biochar can provide an economical, fertilizer-saving alternative under Gwalior conditions. Feedstock selection is therefore agronomically relevant because crop-residue, woody, and invasive-weed biochars can differ in ash content, nutrient composition, stability, and surface properties (Choudhary *et al.,* 2023; Meena *et al*., 2023).

However, evidence remains limited under Gwalior conditions regarding the comparative performance of locally available biochars with full and reduced RDF for Indian mustard, particularly when yield attributes, seed yield and economic returns are evaluated together.

Therefore, the present study was conducted to test the hypothesis that integrating locally available biochar, particularly biochar derived from an invasive weed such as *Lantana camara*, with mineral fertilizers would enhance the productivity and profitability of Indian mustard. The specific objectives of this study were: (1) to evaluate the effect of various biochar-based nutrient management practices on the yield attributes and seed yield of Indian mustard, and (2) to assess the economic viability of reducing the recommended dose of fertilizer (RDF) to 75% when integrated with biochar under Gwalior conditions.

2. Materials and Methods

The experiment was conducted during the *rabi* season of 2025-26 at the Agriculture Research and Development Centre, Sakatpura, School of Agriculture Science, Vikrant University, Gwalior, Madhya Pradesh. The site represents the Gird agro-climatic region, where mustard is commonly cultivated during the cool, dry winter season.

The crop variety was Kranti. The experiment was laid out in a randomised block design with three replications and eight treatments. The gross plot size was 4.0 m × 3.0 m. Mustard was sown at a spacing of 45 cm × 15 cm, with a seed rate of 5 kg ha^{-1}. The recommended dose of fertilizer was 80:40:40:40 kg N:P_2O_5:K_2O:S ha^{-1}. Mustard stover biochar, *Lantana camara* biochar, and wood/forest residue biochar were applied at 5.0 t ha^{-1} according to the treatment combinations.

Yield attributes were recorded from representative plants at harvest. Seed and stover yields were recorded plot-wise and converted to q ha^{-1}. Biological yield was calculated as the sum of seed yield and stover yield, and the harvest index was calculated by dividing seed yield by biological yield and multiplying by 100. The economic analysis was based on the cost of cultivation, gross returns, net returns, and the benefit:cost ratio. Data were statistically analysed according to the randomised block design, and treatment means were compared using the critical difference (CD) at the 5% level, wherever applicable (Gomez & Gomez, 1984).

Table 1. Treatment combinations used in the experiment

Treatment	Treatment details
T_1	Absolute control
T_2	100% RDF (80:40:40:40 kg N:P_2O_5:K_2O:S ha^{-1})
T_3	100% RDF + mustard stover biochar @ 5.0 t ha^{-1}
T_4	100% RDF + lantana biochar @ 5.0 t ha^{-1}
T_5	100% RDF + wood/forest residue biochar @ 5.0 t ha^{-1}
T_6	75% RDF (60:30:30:30 kg N:P_2O_5:K_2O:S ha^{-1}) + mustard stover biochar @ 5.0 t ha^{-1}
T_7	75% RDF (60:30:30:30 kg N:P_2O_5:K_2O:S ha^{-1}) + lantana biochar @ 5.0 t ha^{-1}
T_8	75% RDF (60:30:30:30 kg N:P_2O_5:K_2O:S ha^{-1}) + wood/forest residue biochar @ 5.0 t ha^{-1}

RDF = recommended dose of fertilizer; MSB = mustard stover biochar; LB = lantana biochar; WFB = wood/forest residue biochar

3. Results and Discussion

3.1 Yield Attributes

Biochar-based nutrient management significantly improved yield attributes compared with the absolute control. The highest numbers of siliquae plant^{-1} (340.00) and seeds siliqua^{-1} (14.60), and the highest 1,000-seed weight (5.21 g), were recorded with T_4 (100% RDF + *Lantana camara* biochar @ 5.0 t ha^{-1}). This treatment was statistically at par with T_7 and T_3 for yield-attributing characters, indicating that biochar strengthened reproductive development. The improvement may be linked to better nutrient conservation, root-zone moisture, and dry-matter partitioning in biochar-amended soil. Similar positive effects of biochar-based–nutrient management on yield-attributing characters have been reported by Choudhary *et al*. (2022), Huy et al. (2015), Patel *et al*. (2024), and Sharma *et al*. (2021). The performance of 75% RDF + *Lantana camara* biochar @ 5.0 t

ha^{-1} was consistent with evidence that biochar improves crop nutrient availability and reproductive growth when combined with mineral fertilizer, rather than functioning as an independent nutrient source (Purakayastha *et al*., 2024; Zhang *et al.,* 2022). In addition, biochar-induced changes in soil porosity and water retention may help maintain assimilate supply during flowering and seed filling, particularly in moisture-limited soils (Blanco-Canqui, 2017; Sharma *et al*., 2021).

Table 2. Effect of biochar-based nutrient management on yield attributes of mustard

Treatment	Details	Siliquae $plant^{-1}$	Seeds $siliqua^{-1}$	1000 seed weight (g)
T_1	Control	170.00	10.40	4.05
T_2	100% RDF	303.00	13.60	4.93
T_3	100% RDF + MSB	329.00	14.30	5.12
T_4	100% RDF + LB	340.00	14.60	5.21
T_5	100% RDF + WFB	314.00	13.90	5.00
T_6	75% RDF + MSB	301.00	13.50	4.92
T_7	75% RDF + LB	331.00	14.20	5.10
T_8	75% RDF + WFB	290.00	13.10	4.84
SEm(±)		11.00	0.35	0.11
LSD(p-0.05)		33.00	1.05	0.33

3.2 Yield and Harvest Index

Significantly higher seed yield was recorded with 100% RDF + lantana biochar @ 5.0 t ha^{-1} (21.72 q ha^{-1}), representing a 79.5% improvement over the absolute control and a 16.5% improvement over 100% RDF alone. The treatments 100% RDF + mustard stover biochar @ 5.0 t ha^{-1} (20.84 q ha^{-1}) and 75% RDF (60:30:30:30 kg $N:P_2O_5:K_2O:S$ ha^{-1}) + lantana biochar @ 5.0 t ha^{-1} (20.67 q ha^{-1}) remained close to T_4, indicating that mustard stover and, especially, lantana biochar supported efficient yield formation. The maximum stover yield (44.00 q ha^{-1}) and biological yield (65.72 q ha^{-1}) were also obtained with 100% RDF + lantana biochar @ 5.0 t ha^{-1}. Harvest index varied only slightly among treatments and was non-significant, suggesting that biochar and fertilizer increased seed and stover yields almost proportionately. The yield response agrees with broader evidence that biochar is more effective when combined with fertilizer than when used alone (Ye *et al*., 2020).

Statistically similar yields with 100% RDF + mustard stover biochar @ 5.0 t ha^{-1}, 100% RDF + lantana biochar @ 5.0 t ha^{-1}, and 75% RDF (60:30:30:30 kg $N:P_2O_5:K_2O:S$ ha^{-1}) + lantana biochar @ 5.0 t ha^{-1} suggest that the yield advantage was associated with improved resource availability rather than a marked change in dry-matter partitioning, as reflected by the non-significant harvest index. This interpretation accords with mustard and other field-crop studies in which integrated organic–mineral nutrition increased seed and biomass yields, while the magnitude of the response varied with soil and amendment conditions (Singh *et al.,* 2018; Tripathi *et al*., 2011; Xu *et al*., 2021). Meta-analyses further show that biochar–fertilizer combinations usually produce more reliable yield gains than biochar alone, although responses remain context-dependent (Schmidt *et al.,* 2021; Xu *et al.,* 2021).

Table 3. Effect of biochar-based nutrient management on yield parameters and harvest index of mustard

Treatment	Details	Seed yield (q ha^{-1})	Stover yield (q ha^{-1})	Biological yield (q ha^{-1})	Harvest index (%)
T_1	Control	12.10	25.00	37.10	32.61
T_2	100% RDF	18.65	37.80	56.45	33.04
T_3	100% RDF + MSB	20.84	42.00	62.84	33.16
T_4	100% RDF + LB	21.72	44.00	65.72	33.05
T_5	100% RDF + WFB	19.63	39.80	59.43	33.02
T_6	75% RDF + MSB	18.88	38.20	57.08	33.08
T_7	75% RDF + LB	20.67	41.50	62.17	33.25
T_8	75% RDF + WFB	18.02	36.40	54.42	33.12
SEm(±)		0.72	1.48	2.20	0.34
LSD(p-0.05)		2.16	4.44	6.60	NS

S.Em.± = 0.72, 1.48, 2.20 and 0.34; CD (P=0.05) = 2.16, 4.44, 6.60 and NS for seed yield, stover yield, biological yield and harvest index, respectively

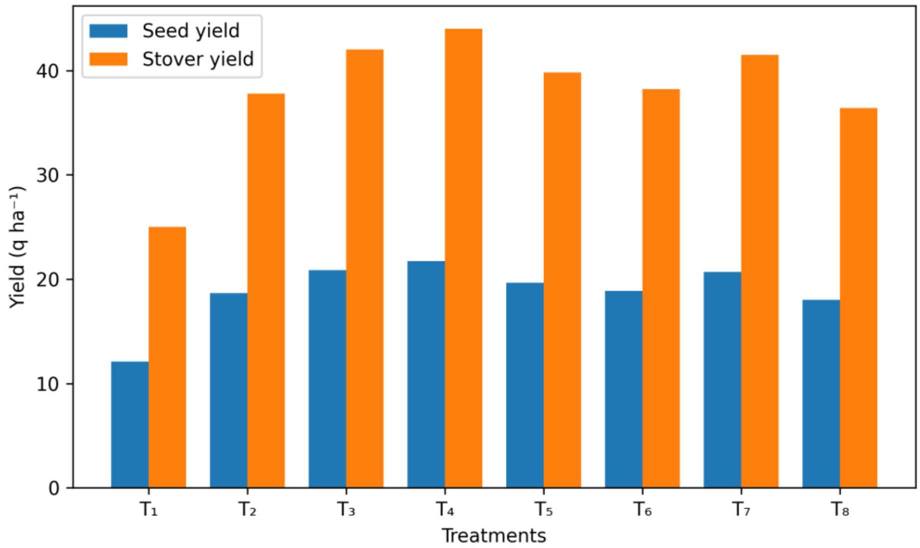

Fig. 1. Seed and stover yield of mustard under biochar-based nutrient management

3.3 Economics

Economic analysis revealed that profitability depended on both yield increase and treatment cost. The highest gross return (₹1,52,320 ha^{-1}) and net returns (₹1,03,720 ha^{-1}) were obtained with 100% RDF + lantana biochar @ 5.0 t ha^{-1} because of the higher seed and stover yields. The treatment comprising 75% RDF (60:30:30:30 kg $N:P_2O_5:K_2O:S$ ha^{-1}) + lantana biochar @ 5.0 t ha^{-1} recorded net returns of ₹98,720 ha^{-1} and the highest benefit:cost ratio (3.14). This indicates that reducing fertilizer application to 75% RDF with *Lantana camara* biochar provided high economic efficiency without compromising agronomic performance, with a seed yield 10.8% higher than that obtained with 100% RDF alone. Treatments involving wood/forest residue biochar were less profitable because of their comparatively lower yields and higher treatment costs. The economic trend supports earlier findings that the most productive treatment is not always the most economical when amendment costs are included (Kumari *et al.,* 2024; Patel *et al.,* 2024; Varma *et al*., 2021). Although the superior B:C ratio was obtained with 75% RDF (60:30:30:30 kg $N:P_2O_5:K_2O:S$ ha^{-1}) + lantana biochar @ 5.0 t ha^{-1}, biochar profitability is sensitive to feedstock availability, processing and transport costs, crop value, and the duration of residual benefits (Campion *et al*., 2023; Galinato et al., 2011). Accordingly, locally sourced lantana biochar may be economically attractive when its preparation and application costs remain low, but the present one-season estimates should not be generalised without multi-season cost accounting (Meena *et al*., 2023; Patel *et al*., 2024; Varma *et al.,* 2021).

Table 4. Effect of biochar-based nutrient management on economics of mustard

Treatment	Details	Cost of cultivation (₹ ha^{-1})	Gross returns (₹ ha^{-1})	Net returns (₹ ha^{-1})	B:C ratio
T_1	Control	34,250	85,100	50,850	2.48
T_2	100% RDF	45,850	130,800	84,950	2.85
T_3	100% RDF + MSB	52,800	146,040	93,240	2.77
T_4	100% RDF + LB	48,600	152,320	103,720	3.13
T_5	100% RDF + WFB	54,200	137,680	83,480	2.54
T_6	75% RDF + MSB	49,250	132,380	83,130	2.69
T_7	75% RDF + LB	46,050	144,770	98,720	3.14
T_8	75% RDF + WFB	50,650	126,320	75,670	2.49

Gross return was calculated from seed and stover yield at prevailing market prices; net return = gross return − cost of cultivation; B:C ratio = gross return/cost of cultivation

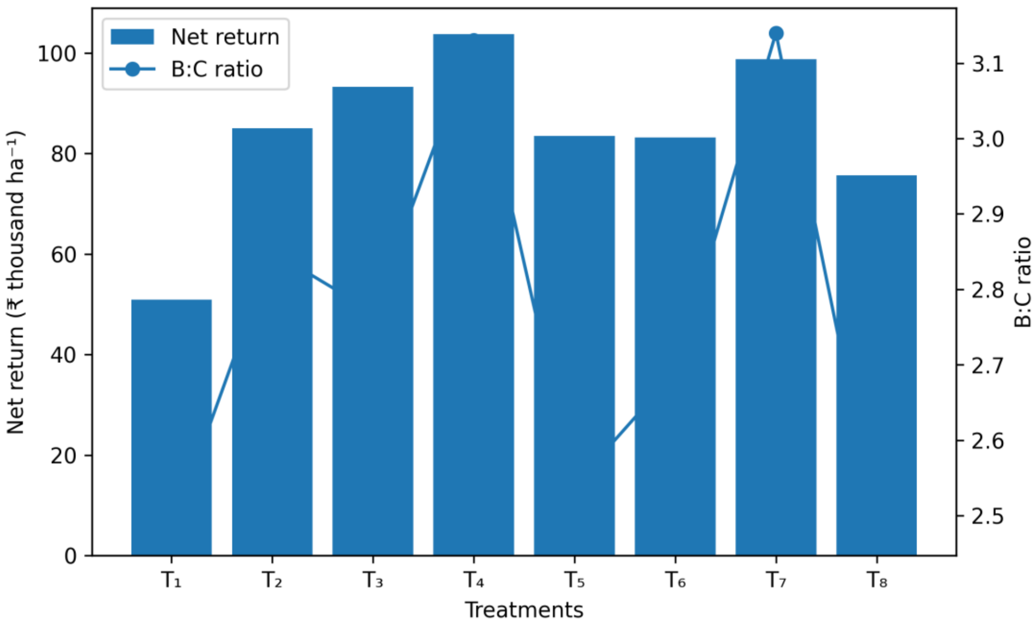

Fig. 2. Net return and benefit:cost ratio of mustard under biochar-based nutrient management

4. Conclusion

The application of 100% RDF combined with Lantana biochar (5.0 t ha^{-1}) was the most effective approach for maximising mustard yield and overall profits. However, reducing fertilizer application to 75% RDF with the same biochar emerged as a practical, cost-saving alternative that delivered comparable yields and the highest benefit–cost ratio. Converting local lantana weeds into biochar may therefore be a profitable strategy for farmers, although these results should be validated over several seasons before broad field recommendations are made.

5. Limitation

The study was conducted at one location during a single rabi season and evaluated biochar application at only one rate. Consequently, seasonal variability, residual effects, changes in soil properties over time, and the influence of location-specific conditions were not assessed. The economic analysis used prevailing market prices and did not examine how variations in feedstock collection, biochar production, transport, and application costs might affect profitability. Multi-season and multi-location studies are therefore needed to confirm the consistency of the observed yield and economic responses.

Acknowledgement

The author acknowledges the School of Agriculture Science, Vikrant University, Gwalior, Madhya Pradesh, for providing the field and academic facilities required to conduct the experiment.

Declaration of AI Use

This manuscript was prepared through the combined contributions of all author(s), including contributions to the study design, data, content development, results, interpretation, and related scholarly work. The author(s) acknowledge the use of Grammarly and ChatGPT to assist with grammar checking, language refinement, reference formatting. These AI-assisted tools were not used as authors and did not replace the intellectual contributions or scholarly judgment of the author(s). All AI-assisted outputs, including content, references, and interpretations, were carefully reviewed, revised, verified, and approved by the author(s). The author(s) accept full responsibility for the accuracy, integrity, and final content of the manuscript.

Competing Interests

Authors have declared that no competing interests exist.

References

Biederman, L. A., & Harpole, W. S. (2013). Biochar and its effects on plant productivity and nutrient cycling: A meta-analysis. *GCB Bioenergy, 5*(2), 202–214. https://doi.org/10.1111/gcbb.12037

Blanco-Canqui, H. (2017). Biochar and soil physical properties. *Soil Science Society of America Journal, 81*(4), 687–711. https://doi.org/10.2136/sssaj2017.01.0017

Campion, L., Bekchanova, M., Malina, R., & Kuppens, T. (2023). The costs and benefits of biochar production and use: A systematic review. *Journal of Cleaner Production, 408*, Article 137138. https://doi.org/10.1016/j.jclepro.2023.137138

Chan, K. Y., Van Zwieten, L., Meszaros, I., Downie, A., & Joseph, S. (2007). Agronomic values of greenwaste biochar as a soil amendment. *Australian Journal of Soil Research, 45*(8), 629–634. https://doi.org/10.1071/SR07109

Choudhary, P., Prasad, M., Choudhary, M., Kumar, A., Kumar, S., Srinivasan, R., & Mahawer, S. K. (2023). Exploring invasive weed biochar as soil amendment: A study on fodder oats productivity and soil biological properties. *Environmental Research, 216*, Article 114527. https://doi.org/10.1016/j.envres.2022.114527

Choudhary, P., Prasad, M., Choudhary, M., Kumar, A., Mahawer, S. K., Srinivasan, R., & Kumar, S. (2022). Effect of invasive weed biochar mixed with inorganic fertilizer on soil physical and chemical properties in semi-arid region of India. *International Journal of Plant & Soil Science, 34*(14), 92–98. https://doi.org/10.9734/IJPSS/2022/v34i1430995

Dayoub, E. B., Ibrahim, J., Hasan, S., & Kajo, O. (2025). The impact of biochar and olive mill wastewater amendments on soil physical and hydrodynamic characteristics and soybean productivity in the Syrian coast. *Asian Journal of Advances in Research, 8*(1), 1–15. https://doi.org/10.56557/ajoair/2025/v8i1500

Essilfie, M. E., Appiah, E., Asiedu, E. K., & Owusu, S. E. (2023). Growth and yield response of maize (*Zea mays* L.) to integrated nutrient management of biochar, organic and inorganic fertilizers. *Asian Journal of Advances in Agricultural Research, 23*(4), 69–91. https://doi.org/10.9734/ajaar/2023/v23i4481

Galinato, S. P., Yoder, J. K., & Granatstein, D. (2011). The economic value of biochar in crop production and carbon sequestration. *Energy Policy, 39*(10), 6344–6350. https://doi.org/10.1016/j.enpol.2011.07.035

Glaser, B., Lehmann, J., & Zech, W. (2002). Ameliorating physical and chemical properties of highly weathered soils in the tropics with charcoal: A review. *Biology and Fertility of Soils, 35*(4), 219–230. https://doi.org/10.1007/s00374-002-0466-4

Gomez, K. A., & Gomez, A. A. (1984). *Statistical procedures for agricultural research* (2nd ed.). John Wiley & Sons. https://www.wiley.com/en-us/shop/general-introductory-agriculture/statistical-procedures-for-agricultural-research-2nd-edition-p-9780471870920

Huy, S., Borin, K., & Preston, T. R. (2015). Carry-over effects of biochar on yield of mustard green vegetable (*Brassica juncea*) and on soil fertility. *Livestock Research for Rural Development, 27*(9), Article 184. https://www.lrrd.org/lrrd27/9/sock27184.html

Jat, R. S., Singh, V. V., Sharma, P., & Rai, P. K. (2019). Oilseed Brassica in India: Demand, supply, policy perspective and future potential. *OCL, 26*, Article 8. https://doi.org/10.1051/ocl/2019005

Jeffery, S., Verheijen, F. G. A., van der Velde, M., & Bastos, A. C. (2011). A quantitative review of the effects of biochar application to soils on crop productivity using meta-analysis. *Agriculture, Ecosystems & Environment, 144*(1), 175–187. https://doi.org/10.1016/j.agee.2011.08.015

Kumari, N., Sinha, A. K., Kumar, S. B., Shahi, D. K., Kumari, N., Pandey, S. K., & Baxla, K. J. (2024). Effect of applied biochar on productivity of linseed. *Plant Archives, 24*(2), 332–336. https://doi.org/10.51470/PLANTARCHIVES.2024.v24.no.2.045

Lehmann, J., & Joseph, S. (Eds.). (2015). *Biochar for environmental management: Science, technology and implementation* (2nd ed.). Routledge. https://doi.org/10.4324/9780203762264

Liu, X., Zhang, A., Ji, C., Joseph, S., Bian, R., Li, L., Pan, G., & Paz-Ferreiro, J. (2013). Biochar's effect on crop productivity and the dependence on experimental conditions: A meta-analysis of literature data. *Plant and Soil, 373*(1–2), 583–594. https://doi.org/10.1007/s11104-013-1806-x

Meena, S., Choudhary, R., Sharma, S. K., Choudhary, J., Jat, G., Dubey, R. B., Yadav, S. K., Jain, R. K., & Choudhary, R. (2023). Effect of Lantana biochar on yield and economics of organic chickpea (*Cicer* *arietinum* L.). *The Pharma Innovation Journal, 12*(6), 2801–2803. https://www.thepharmajournal.com/archives/?ArticleId=20801&issue=6&vol=12&year=2023

Patel, P. R., Kumawat, P. D., Chaudhari, R. J., Chaudhari, N. N., & Patel, Z. B. (2024). Effect of integrated nutrient management on growth, yield and economics of Indian mustard (*Brassica juncea* L.). *Biological Forum – An International Journal, 16*(7), 76–82. https://www.researchtrend.net/bfij/effect-of-integrated-nutrient-management-on-growth-yield-and-economics-of-indian-mustard-brassica-juncea-l-8638

Purakayastha, T. J., Bera, T., Dey, S., Pande, P., Kumari, S., & Bhowmik, A. (2024). Biochar aided priming of carbon and nutrient availability in three soil orders of India. *Scientific Reports, 14*, Article 8420. https://doi.org/10.1038/s41598-024-56618-w

Schmidt, H.-P., Kammann, C., Hagemann, N., Leifeld, J., Bucheli, T. D., Sánchez Monedero, M. A., & Cayuela, M. L. (2021). Biochar in agriculture: A systematic review of 26 global meta-analyses. *GCB Bioenergy, 13*(11), 1708–1730. https://doi.org/10.1111/gcbb.12889

Sharma, P., Abrol, V., Sharma, V., Chaddha, S., Rao, C. S., Ganie, A. Q., Hefft, D. I., El-Sheikh, M. A., & Mansoor, S. (2021). Effectiveness of biochar and compost on improving soil hydro-physical properties, crop yield and monetary returns in Inceptisol subtropics. *Saudi Journal of Biological Sciences, 28*(12), 7539–7549. https://doi.org/10.1016/j.sjbs.2021.09.043

Singh, R. K., Kumar, P., Singh, S. K., Singh, S. B., & Singh, R. N. (2018). Effect of integrated nutrient management on yield and economics of mustard (*Brassica juncea* L.). *International Journal of Current Microbiology and Applied Sciences, Special Issue 7*, 5261–5269. https://www.ijcmas.com/special/7/Rama%20Kant%20Singh%2C%20et%20al.pdf

Tripathi, M. K., Chaturvedi, S., Shukla, D. K., & Saini, S. K. (2011). Influence of integrated nutrient management on growth, yield and quality of Indian mustard (*Brassica juncea* L.) in the tarai region of northern India. *Journal of Crop and Weed, 7*(2), 104–107. https://www.cropandweed.com/archives/2011/vol7issue2/23.pdf

Varma, G. R., Satish, P., Hussain, S. A., & Sharma, S. H. K. (2021). Effect of integrated nutrient management on productivity and economics of Indian mustard (*Brassica juncea* L.). *International Journal of Environment and Climate Change, 11*(6), 169–176. https://doi.org/10.9734/ijecc/2021/v11i630433

Wang, L., Leghari, S. J., Wu, J., Wang, N., Pang, M., & Jin, L. (2023). Interactive effects of biochar and chemical fertilizer on water and nitrogen dynamics, soil properties and maize yield under different irrigation methods. *Frontiers in Plant Science, 14*, Article 1230023. https://doi.org/10.3389/fpls.2023.1230023

Xiao, L., Lin, Y., Chen, D., Zhao, K., Wang, Y., You, Z., Zhao, R., Xie, Z., & Liu, J. (2024). Maximizing crop yield and water productivity through biochar application: A global synthesis of field experiments. *Agricultural Water Management, 305*, Article 109134. https://doi.org/10.1016/j.agwat.2024.109134

Xu, H., Cai, A., Wu, D., Liang, G.-P., Xiao, J., Xu, M., Colinet, G., & Zhang, W. (2021). Effects of biochar application on crop productivity, soil carbon sequestration, and global warming potential controlled by biochar C ratio and soil pH: A global meta-analysis. *Soil and Tillage Research, 213*, Article 105125. https://doi.org/10.1016/j.still.2021.105125

Xu, Z., Zhou, R., & Xu, G. (2025). Global analysis on potential effects of biochar on crop yields and soil quality. *Soil Ecology Letters, 7*(1), Article 240267. https://doi.org/10.1007/s42832-024-0267-x

Ye, L., Camps-Arbestain, M., Shen, Q., Lehmann, J., Singh, B., & Sabir, M. (2020). Biochar effects on crop yields with and without fertilizer: A meta-analysis of field studies using separate controls. *Soil Use and Management, 36*(1), 2–18. https://doi.org/10.1111/sum.12546

Zhang, L., Zhang, M., Li, Y., Li, J., Jing, Y., Xiang, Y., Yao, B., & Deng, Q. (2022). Linkage of crop productivity to soil nitrogen dynamics under biochar addition: A meta-analysis across field studies. *Agronomy, 12*(2), Article 247. https://doi.org/10.3390/agronomy12020247

Peer-review history:
The peer review history for this paper can be accessed here:
https://pr.sdiarticle5.com/review-history/164024