D-6420
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RESEARCH ARTICLE Agricultural Science Digest

Effect of Biochar and Biofertilizers on Productivity and Profitability of Mung Bean (*Vigna radiata* L.) in Semi-arid Eastern Plain Zone of Rajasthan

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10.18805/ag.D-6420

ABSTRACT

Background: Low yields of pulses in India are mainly due to the use of poor-quality seeds, cultivation on marginal soils with low inputs, inadequate pest and disease management, moisture stress and unscientific post-harvest and storage practices. In this context use of alternative sources of plant nutrients such as bio-fertilizers and organic sources is the need of the time.

Methods: The present study aimed to evaluate the response of biochar and biofertilizers on productivity and profitability of mung bean (*Vigna radiata* L.) in Semi-arid Eastern Plain Zone of Rajasthan. A field experiment was conducted during *kharif* season (2021) on mung bean at SKN College of Agriculture, Jobner (Rajasthan). The experiment was laid out in factorial randomized block design with three replications, Consisted of four levels of biochar (control, 2.0, 4.0 and 6.0 ton/ha) and four treatment of biofertilizers (Control, *Rhizobium*, *PSB* and *Rhizobium* + *PSB*).

Result: The results revealed that the application of biochar @ 4.0 ton/ha produced significantly higher number of pods/plant, number of seeds/pod, pod length, seed yield (1151 kg/ha), straw yield (2547 kg/ha) and biological yield (3816 kg/ha) and net returns (₹49910/ha) of mung bean over control and application of biochar @ 2.0 ton/ha. However, it was at par with 6.0 ton/ha biochar for almost all parameters. Further, the B: C ratio of mung bean decreased as biochar levels increased and highest B:C ratio was obtained in control. Results further showed that seed inoculation with *Rhizobium* + *PSB* significantly increased the number of pods/plant, number of seeds/pod, pod length, seed yield (1158 kg/ha), straw yield (2564 kg/ha) and biological yield (3722 kg/ha), net returns (₹57311/ha) and B: C ratio (2.36) of mung bean.

Key words: Biochar, Biofertilizers, Economics, Mung bean, Yield.

INTRODUCTION

Pulse crops play an important role in Indian agriculture and India is the largest producer and consumer of pulses in the world. Pulses contains high percentage of quality protein nearly three times as much as cereals (Upadhayay *et al*., 1999). Thus, they are cheaper source to overcome protein malnutrition among human beings. Pulses are drought resistant and prevent soil erosion due to their deep root and good ground covers, because of these good characters, pulses are called as “Marvel of Nature”. Mung bean [*Vigna radiata* (L.) Wilczek] is an important pulse crop in India grown principally for its protein rich edible seeds. It belongs to the sub-family *Papilionaceae* under the family *Leguminaceae*. India is the largest grower of mung bean with cultivating area 40.70 lakh ha as well as producer with an annual production and average productivity statistics of 19.01 lakh tons and 472 kg /ha, respectively (Anonymous, 2019). In Rajasthan, total area under mung bean was 25.60 lakh hectares with the production of 9.05 lakh tonnes and productivity of 354 kg/ha (Anonymous, 2021). Despite of being such an important crop, the average productivity of mung bean in the state is quite low compared to its production potential which is a matter of serious concern.

The factors attributed for low yields of pulses in India as compared to the world productivity are non- availability of quality seeds of improved and short duration varieties, growing of pulses on marginal and less fertile soil with low inputs and without pest and disease management, growing of pulses under moisture stress, unscientific post-harvest practices and storage under unfavourable conditions. More over injudicious use of chemical fertilizers enhanced the soil and plant health problems. In this context use of alternative sources of plant nutrients such as bio-fertilizers and organic sources is the need of the time. In

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How to cite this article: Kumar, N., Dudwal, B.L., Mandeewal, R.L. and Choudhary, R. (2025). Effect of Biochar and Biofertilizers on Productivity and Profitability of Mung Bean (*Vigna radiata* L.) in Semi-arid Eastern Plain Zone of Rajasthan. *Agricultural Science Digest.* 1-5. doi: 10.18805/ag.D-6420.

Submitted: 28-07-2025 **Accepted:** 17-12-2025 **Online:** 10-01-2026

recent years, biochar has emerged as an organic amendment with mineral nutrient elements and hold promise to improve the soil quality and yield of crops. The biochar is found to have positive impact on soil fertility, resulting in an increase in crop yield without causing hazard to soil and water environment. Biochar produced from varied technological methods of pyrolysis can convert agriculture crop residues like coconut shells, arecanut husks, maize cob, cereal-pulse crop husks, grasses, forestry products, animal and poultry manures to biochar. Looking at the potential use of biochar in agriculture, there is a need to assess the suitability of such feed stocks which otherwise are type of waste material.

On the other hand, use of biofertilizers can have a greater importance in increasing fertilizer use efficiency. Biofertilizer is a matter of living micro-organisms that are applied to plant surfaces or soil, grains, colonize the rhizosphere or the inside of the plant and promote growth through increasing availability of primary nutrients to the crop plant. The seed of pulses is inoculated with *Rhizobium* with an objective of increasing their number in the rhizosphere, so that there is substantial increase in the microbiologically fixed nitrogen for the plant growth. The inoculation of seeds with suitable *Rhizobium* culture increased the green pod yield over un- inoculated control (Athul *et al.,* 2022). Most soil of Rajasthan is poor in phosphorus supply and low in organic matter. Seed of pulses when inoculated with phosphate solubilizing bacteria, *PSB* secret acetic substances and solubilize unavailable soil phosphorus. The inoculation with phosphate solubilizing bacteria biofertilizer may increase yield of crops by 7-14 per cent (Mohapatra *et al*., 2024). Therefore, the present study was planned to assessment of how various combinations of biochar and biofertilizer applications impact growth parameters, yield components and economic returns of mung bean (*Vigna radiata* L.).

MATERIALS AND METHODS

A field experiment was conducted at Agronomy Farm, SKN College of Agriculture, Jobner, Rajasthan (26°05′N, 75°28′E, 427 m AMSL) in loamy sand soil during *Kharif* 2021. The experiment was conducted in factorial randomized block design and replicated thrice. Treatments Consisted of 4 biochar levels (0, 2.0, 4.0 and 6.0 t/ha) and 4 biofertilizer treatments (Control, *Rhizobium*, *PSB*, *Rhizobium* + *PSB*). Mung bean variety MH-421 was sown on 20th July. The climate of this region is typically semi-arid, characterized by extremes of temperature during both summers and winters. During summers, the temperature may go as high as 48°C, while in winters, it may fall as low as -1.0°C. The average annual rainfall of this tract ranges between 400-500 mm, most of which is contributed by the South west monsoon during July and August. There is hardly any rain during winter and summers. The maximum and minimum temperatures during the crop season ranged between 30.9°C to 38.2°C and 13.0°C to 25.7°C, respectively. A total of 311.7 mm rainfall was recorded during the cropping season. The relative humidity Vary between 50 to 89 per cent, while the average sunshine hours ranged between 1.5 to 9.9 hrs/day. Standard crop management practices were adopted. Observations were recorded for yield attributes, yield and economic parameters. MH-421 variety of mung bean was released by CCSHAU, Hisar in 2014. Its average plant height is 50-70 cm and this variety matures in 60 to 65 days. Its average yield is 1000-1200 kg/ha. The variety is tolerant to yellow mosaic disease. The variety is suitable for north western plain zone of India. *Lantana camera*-based biochar was collected from Udaipur. The nutrient content of the biochar was determined one week before application to ascertain the amount of nutrients applied. Biochar applied according to the treatments two week before sowing. However with regard to application, Seed treatment with liquid based biofertilizers was done by taking the liquid culture of biofertilizer @ 5 ml of formulation and dissolved in sufficient quantity of water to treat one kg seed. The seeds are well coated with the solution and dried under the shade before sowing.

RESULTS AND DISCUSSION

Effect of biochar and biofertilizers on yield attributes of mung bean

Application of biochar and biofertilizers significantly influenced key yield attributes of mung bean. Biochar at 4.0 t/ha consistently resulted in the highest number of pods per plant, seeds per pod and pod length, Which was found to be at par with 6.0 t/ha and significantly better than lower doses and (Table 1). Application of 4.0 t/ha biochar increased pods/plant by 34.4%, seeds/pod by 19.6% and pod length by 17.4% over the control. Similarly, seed

Table 1: Effect of biochar and biofertilizers on yield attributes of mung bean.

Treatment	Pods/ plant	Seeds/ pod	Pod length (cm)	100 seed weight (g)
Biochar (t/ha)				
Control	16.6	9.1	6.6	34.2
2.0	19.7	10.0	7.1	35.0
4.0	22.3	10.8	7.7	35.4
6.0	23.2	11.0	7.8	35.6
SEm(±)	0.5	0.3	0.2	0.9
CD (5%)	1.5	0.7	0.4	NS
Biofertilizers				
Control	17.7	9.0	6.65	34.3
Rhizobium	21.1	10.4	7.38	34.8
PSB	20.2	10.1	7.25	35.4
Rhizobium + *PSB*	22.7	11.4	7.90	35.7
SEm(±)	0.5	0.3	0.16	0.9
CD (5%)	1.5	0.7	0.45	NS

inoculation with *Rhizobium* + PSB significantly enhanced yield attributes compared to individual inoculations and control. This treatment improved pods/plant by 28.7%, seeds/pod by 25.7% and pod length by 18.8% over the control. However, neither biochar nor biofertilizer treatments Recorded significant effect on 100 seed weight. These findings Emphasis synergistic role of biochar and biofertilizer combinations in improving mung bean productivity under semi-arid conditions. The combined use of biochar and biofertilizers showed promising potential in improving mung bean productivity under semi-arid conditions. The results of the present investigation corroborate the findings of Joshua *et al.* (2025); Budhina *et al*. (2014); Agegnehu *et al.* (2015); Ndor *et al*. (2015) and Glodowska *et al*. (2017). This favourable effect of bacterial inoculation could be attributed to increased solubilization of mineral phosphates and other nutrients and also increase nitrogen and phosphorus supply in inoculated plot due to nitrogen fixation and phosphorus solubilization ability of these bacteria and which is ultimately increased all the yield attributes of mung bean. The result of present study in close conformity with the findings of Tilak and Annapurna (1993); Wayase *et al*. (2014); Hadiyal *et al.* (2017); Beenish *et al.* (2019) and Parmar *et al*. (2020).

Effect of biochar and biofertilizers on yield of mung bean

Application of biochar and biofertilizers significantly enhanced the seed yield, straw yield and biological yield of mung bean (Table 2). Among biochar treatments, 4.0 t/ha and 6.0 t/ha recorded the highest seed yield (1151 and 1186 kg/ha, respectively), with increases of up to 47.6% over control. Straw and biological yields also improved notably, with 4.0 t/ha biochar resulting in 44.2% increase in straw yield and 45.2% increase in biological yield over control. Similarly, seed inoculation with *Rhizobium* + *PSB* produced significantly higher seed yield (1158 kg/ha), straw yield (2564 kg/ha) and biological yield (3722 kg/ha) than individual inoculations and control. The respective increases in seed yield, straw yield and biological yield over control were 36.0%, 33.2% and 34.1%. However, harvest index remained statistically unaffected by both biochar and biofertilizer treatments. A positive effect of biofertilizer inoculations on seed and straw yields might be due to more population of *Rhizobium* and phosphate solubilizing bacteria, better survival of inoculated microorganisms in the rhizosphere and seed surface due to presence of cell protectant chemicals such as polyvinylpyrrolidone and trehalose. Application of biofertilizer enhanced high number of cells in the rhizosphere, multiplication and subsistence of cells due to availability of carbon and energy sources. The use of biofertilizers may lead to higher availability of macro and micronutrients that promoted growth and development and ultimately resulting in higher yields. These results are in the line with the findings of Kumar *et al.* (2018); Kalita *et al.* (2019); Mane *et al*. (2019); Samant (2020); Aglawe *et al.* (2021) and Parmar *et al.* (2021); Arun and Thippeshappa (2023).

Effect of biochar and biofertilizers on economics of mung bean

It is evident from the presented in Table 3 that net returns of mung bean were influenced to a great extent due to different levels of biochar as compared to control. Significantly highest net returns (₹49910/ha) was obtained with application of 4.0 ton biochar/ha over control. It is obvious because higher seed and straw yields obtained with this treatment. However, B: C ratio decreased with an increase in the level of biochar incorporation in soil due to its higher cost. Similarly, Shahzad *et al*. (2018) also revealed that despite the benefits of biochar on yield, it was not economically profitable due to high application rates and price. Application of bio-fertilizers brought about a significant improvement in net returns (₹57117/ha) and B: C ratio (2.36) of mung bean (Table 3). The highest net returns and B: C ratio recorded under inoculation of seeds with *Rhizobium* + *PSB*. This might be due to increased yield in these treatments. These finding are similar to the

Table 2: Effect of biochar and biofertilizers on yield of mung bean.

Treatment	Seed yield (kg/ha)	Straw yield (kg/ha)	Biological yield (kg/ha)	Harvest index (%)
Biochar (t/ha)				
Control	780	1766	2546	30.7
2.0	973	2226	3199	30.4
4.0	1151	2547	3698	31.1
6.0	1186	2630	3816	31.1
SEm(±)	21	54	72	0.4
CD (5%)	61	157	208	NS
Biofertilizers				
Control	852	1925	2776	30.7
Rhizobium	1050	2348	3399	30.9
PSB	1030	2331	3361	30.6
Rhizobium + *PSB*	1158	2564	3722	31.1
SEm(±)	21	54	72	0.4
CD (5%)	61	157	208	NS

Table 3: Effect of biochar and biofertilizers on economics of mung bean.

Treatment	Net returns (₹/ha)	B:C ratio
Biochar (t/ha)		
Control	44678	2.70
2.0	48396	2.20
4.0	49910	1.92
6.0	39127	1.57
Biofertilizers		
Control	30408	1.76
Rhizobium	48010	2.16
PSB	46381	2.12
Rhizobium + *PSB*	57311	2.36

results obtained by Joshi *et al.* (2018); Kalita *et al.* (2019); Aglawe *et al.* (2021) and Jerusha *et al.* (2021).

CONCLUSION

The application of biochar at 4.0 ton per hectare significantly increased mung bean seed yield by improving soil structure, water retention, nutrient availability and microbial activity. This treatment was economically viable for farmers in semi-arid regions. Inoculating mung bean seeds with Rhizobium and Phosphate Solubilizing Bacteria was the most effective, producing the highest seed yield of 1158 kg/ha and maximum net returns of ₹ 57,311 per hectare, along with the highest benefit-cost ratio of 2.36, indicating excellent profitability. The yield increase is attributed to improved nitrogen fixation and phosphorus availability, enhancing root development, pod formation and overall plant vigor.

ACKNOWLEDGEMENT

The present study was supported by the Department of Agronomy, SKN Agriculture University Jobner, whose valuable resources and technical assistance greatly contributed to the successful completion of this research.

Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

Informed consent

All animal procedures for experiments were approved by the Committee of Experimental Animal care and handling techniques were approved by the University of Animal Care Committee.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript.

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