



RESEARCH COMMUNICATION

Effect of sulphur and biofertiliser use on yield and economic sustainability of mungbean (*Vigna radiata* L.)

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Received: 02 September 2025; Accepted: 11 December 2025; Available online: Version 1.0: 27 January 2026

Cite this article: Vipul KR, Karuna S, Mukesh KS, Vijay KS, Ramandeep S, Manisha C. Effect of sulphur and biofertiliser use on yield and economic sustainability of mungbean (*Vigna radiata* L.). Plant Science Today. 2026; 13(sp1): 1-5. <https://doi.org/10.14719/pst.11596>

Abstract

A field trial was conducted at agriculture research farm, Lovely Professional University, Phagwara during Kharif season 2021 to study impact of sulphur and biofertilisers on yield and economic sustainability of mungbean. The experiment was conducted in Randomised Block Design with three replications. There were 9 treatments as follows: RDF, RDF + G₁-Gypsum (20 kg/ha), RDF + G₂-Gypsum (30 kg/ha), RDF + G₁+ PSB, RDF + G₂+ PSB, RDF + G₁+ SOB, RDF + G₂+ SOB, RDF + G₁+ PSB + SOB and RDF + G₂+ PSB + SOB. The results showed that amongst treatments, pods/plant (65.94), pod length (19.17 cm) and 1000-seed weight (61.73 g), seed yield (1597.67 kg ha⁻¹) and biological yield (3565.87 kg ha⁻¹) on per ha basis, gross returns (117000 ₹ ha⁻¹) and B: C ratio (4.19) were significantly more in RDF + G₂+ PSB + SOB treatment than rest of the treatments except RDF + G₁+ PSB + SOB treatment. Use of biofertilisers and gypsum can be beneficial in terms of economics as well as for maintaining the soil fertility of the soil.

Keywords: food; economic; gypsum; legume; productivity; sustainability

Introduction

Pulses are an inclusive achievement of food crops that help to solve national food and nutritional security while addressing environmental issues also. Pulses are an important part of the food basket and a good source of protein (20-25 %). Pulses are not only high in protein and amino acids, but they also help to maintain soil fertility by fixing nitrogen in a symbiotic relationship with *Rhizobium* bacteria found in their root nodules. As a result, each pulse plant is regarded as a mini-fertiliser factory in and of itself (1).

Mungbean (*Vigna radiata* L.) of the plant family Fabaceae is native to Indian subcontinent and is primarily grown in India and China. It is the hardiest of the pulse crops, requiring a hot temperature for germination and growth. It can be used as cattle feed and seed husk can be soaked in water and utilised as cattle feed. Because of its greater adaptability, it is widely farmed throughout tropical and subtropical Asia. Mungbean is well known for its detoxifying bioactivities as a significant plant-derived food resource. Mungbean seed is more palatable, nutritive, digestible and non-flatulent than other pulses and it is also a good source of easily digestible, high-quality protein (24 %) and rich in vitamin B9 or folic acid; thus, mungbean has been known to add much-needed variety of cereal-based diets to the poor (2). Mungbean contains vitamin A (94 mg), iron (7.3 mg), calcium (124 mg), zinc (3 mg) and folate (549

mg) per 100 g dried seed (3). In South Asia, it is consumed as dhal and in food products like fried appetisers, sweets and sprouts (4).

Mungbean is grown in roughly 4.5 m ha in India, with 2.5 m t production and 5.48 q ha⁻¹ productivity (5). More than 95 % of the food grain producing land in Punjab and West Bengal is now under rice and wheat cultivation. The insufficient use of organic fertilisers, with less than 1 ton of organic matter supplied to the soil per ha. This is causing a significant drop in soil OM content, particularly in Punjab (0.2 % C content) (6). Mungbean is especially important in sustainable agriculture because it improves soil health by retaining long-term fertility and enriching nitrogen status. Because pulses are a short-term crop, they can be cultivated as a main crop, an intercrop, a catch crop or a green manure crop (7).

Pulses are significant in an agricultural system since they enhance soil health and nutrient supply potential (8). Phosphorus and nitrogen are critical nutrients for grain legumes. Phosphorus is essential for all plant cell energy metabolisms, but especially for nitrogen fixation in legume crops. Phosphorus is required for the growth of large root systems, nodule development and strong seedlings. Sulphur, in addition, is a key nutrient required by legumes. However, it has been observed that Indian soil is low in sulphur. Sulphur deficiency is widespread in Indian soil due to widespread usage of non-sulphur fertiliser combined with significant cultivation

of high sulphur-demanding crops. Sulphur is an important component in higher pulse synthesis because it is essential for the development of proteins, vitamins, enzymes and amino acid components cystine, cysteine and methionine (9). The source of calcium and sulphur that is used in pulses around the globe is usually gypsum. Most farmers apply gypsum in order to achieve higher production of pulses and groundnut (10). In case of groundnut crop, use of gypsum in split doses facilitates calcium and sulphur requirements for improved shell development stages of plant growth (11).

Biofertilizer, a component of integrated nutrition management, plays an essential function in pulse crops by assisting in the improvement of growth parameters and morphological parameters such as root length, branch length, number of leaves and so on. Farmers benefit economically from seed treated with biofertiliser. PSBs such as *Pseudomonas* and *Bacillus* increase phosphorus availability to plants by converting insoluble form in soil to soluble phosphorus. Seed inoculation of PSB with *Rhizobium* would enhance branches and nodules / plant along with production (12). Therefore, the usage of these biofertilisers lowers environmental contamination caused by the intensive use of chemical fertilisers (13,14). Thus, a trial was conducted to evaluate influence of sulphur and biofertilisers on mungbean productivity and profitability in sandy loam, with the goal of determining effect of different sulphur dosages on mungbean production and profitability.

Materials and Methods

The study was conducted during Kharif season 2021 at the agriculture research farm, Lovely Professional University, Phagwara, Punjab. The pH of the experimental soil was 7.5 with sandy loam texture. It had a low organic carbon concentration (0.23 %), low accessible nitrogen content (126.3 kg ha⁻¹) and a medium phosphorus (8.23 kg ha⁻¹) and potassium content (168.3 kg ha⁻¹). The experimental site's mean maximum and minimum temperatures are 38.21 °C and 27.91 °C respectively. The total rainfall for the crop season was 415 mm, with the majority falling on 21 rainy days. The experiment was set up in a Randomised Block Design with three replications. The 9 nutrient management solutions that combine sulphur and biofertilisers viz. RDF (Recommended dose of fertilisers), RDF + G₁ (Gypsum @ 20 kg/ha), RDF + G₂ (Gypsum @ 30 kg/ha), RDF + G₁ + PSB (Phosphorus solubilising bacteria), RDF + G₂ + PSB, RDF + G₁ + SOB (Sulphur oxidizing bacteria), RDF + G₂ + SOB, RDF + G₁ + PSB + SOB and RDF + G₂ + SOB + PSB were tested during experiment. Before planting, 25 kg N ha⁻¹ through urea, 50 kg P ha⁻¹ through single super phosphate and 25 kg K₂O ha⁻¹ through muriate of potash were drilled. Gypsum doses of 20 and 30 kg/ha were applied using gypsum as per treatment. Mungbean seeds were injected with biophos liquid fertiliser at 5 mL/kg seed and sulphur oxidizing bacteria (SOB) at 5 mL/kg seed 2-3 hr before sowing and seeds were properly mixed and allowed to dry in shade before being utilised for sowing in demarcated plots. Mungbean 'MH421' was sown with a seed drill on July 16, 2021, with 30 cm × 10 cm spacing and 20 kg ha⁻¹ of seed rate. Two hand weeding at 15 and 30 DAS and one application of pre-emergence herbicide, pendimethalin @ 1.0 a.i. kg/ha sprayed on the same day of sowing are recommended for effective weed management in mungbean. On 20th October 2021, the crop was harvested to evaluate the biological, seed and stalk yields from plot area. Bundles were neatly knotted and labelled in each plot before being moved to threshing floor for adequate sun

drying. Later, the product was weighed on an electric balance and threshed by hand using wooden sticks and winnowed conventionally.

Sampling and observations yield attributes and yield

Total capsules of 5 tagged plants were counted at harvest from each plot. Ten capsules were taken and number of seeds were counted to get average number of seeds/capsules. The pod length of each plant was measured from 5 observation plants and their mean was taken. Five 1000-grains samples from each plot and weighed and mean was presented in grams. Dried seed of each net plot including those that were tagged was dried by sun and reported as kg/ha treatment by treatment. The biological yield was subtracted with the seed yield to arrive at the straw yield in kg/ha. The net harvest of the plot area was taken and measured in kg/ha to show the biological yield.

Economics

The economics of any treatment, which is the utmost factor to consider prior to any suggestion on whether to adopt the treatment by the farmers. The gross returns (₹ ha⁻¹) resulted as a result of various treatments in the current study were calculated considering the market prices of economic product, by product and crop residues in the year of experiment. The net returns were determined by deducting the total cost of cultivation to gross returns, which were in terms of (₹ ha⁻¹). To determine the benefit gained on the treatments done, the economics of various treatments were calculated as below in terms of net return (₹ ha⁻¹) and B:C ratio (eqn 1) such that the majority of remunerative treatment can be suggested. This was calculated on treatment yield basis and prevailing market rates of inputs and outputs. Cost of cultivation and gross income (₹ ha⁻¹) of various treatments were calculated on the basis of the approved market rates for inputs and outputs fixed by agriculture research farm, Lovely Professional University, Phagwara during the year of experimentation.

$$\text{B:C Ratio} = \frac{\text{Gross returns (₹/ha)}}{\text{Cost of cultivation (₹/ha)}} \quad (\text{Eqn. 1})$$

Statistical analysis

To determine the statistical level of variability in experimental data accrued under different treatment effects, data were analysed according to the procedure that was described (15). The critical differences were also calculated to determine the significance of the treatment means, where the F-test was significant at 5 % probability level.

Results and Discussion

Yield attributes

Data (Table 1) on the yield attributes as affected by application of gypsum and biofertilisers like phosphorus solubilising bacteria and sulphur oxidizing bacteria.

During experimentation observed that the treatment including higher dose of gypsum and 2 bioinoculants i.e. RDF + G₂ - 30 kg gypsum/ha + PSB + SOB recorded significantly more pods/plant (65.94), seeds/pod (13.7), pod length (19.17 cm) and 1000-seed weight (61.73 g) followed by lower dose of gypsum with same bioinoculants i.e. RDF + G₁ - 20 kg gypsum/ha + PSB + SOB and showed significant superiority over all other treatments. The significantly lower pods plant⁻¹, pod length, seeds pod⁻¹ and 1000-

Table 1. Effect of PSB, sulphur oxidizing bacteria and gypsum on yield attributes of mungbean

| Treatments | Yield attributes | | | |
|-------------------------------------|------------------|------------|-----------------|----------------------|
| | Pods/plant | Seeds/pod | Pod length (cm) | 1000 seed weight (g) |
| RDF | 22.27±1.27 | 9.67±0.13 | 10.47±0.37 | 30.96±0.87 |
| RDF + Gypsum (20 kg/ha) | 30.13±2.49 | 9.80±0.70 | 12.43±0.07 | 38.09±1.52 |
| RDF + Gypsum (30 kg/ha) | 35.67±1.45 | 10.20±0.23 | 13.03±0.58 | 40.57±0.82 |
| RDF + PSB + Gypsum (20 kg/ha) | 44.13±3.28 | 10.73±0.41 | 15.10±0.44 | 47.90±1.38 |
| RDF + PSB + Gypsum (30 kg/ha) | 45.13±2.43 | 11.73±0.55 | 15.83±0.10 | 49.50±2.33 |
| RDF + SOB + Gypsum (20 kg/ha) | 45.80±3.28 | 11.93±0.93 | 16.30±0.35 | 50.27±2.38 |
| RDF + SOB + Gypsum (30 kg/ha) | 50.93±2.95 | 12.27±0.24 | 16.63±0.24 | 51.13±3.23 |
| RDF + SOB + PSB + Gypsum (20 kg/ha) | 60.67±0.96 | 12.80±0.31 | 18.73±0.22 | 58.27±2.31 |
| RDF + SOB + PSB + Gypsum (30 kg/ha) | 65.94±2.47 | 13.67±0.42 | 19.17±1.73 | 61.73±3.00 |
| SEm± | 2.49 | 0.52 | 0.65 | 2.27 |
| CD (5%) | 7.47 | 1.56 | 1.95 | 6.82 |

RDF – Recommended dose of fertiliser, PSB – Phosphorus solubilising bacteria, SOB – Sulphur oxidizing bacteria

seed weight was recorded in alone RDF as compared to all the other treatments. Seeds/pod recorded in RDF + G₁ + PSB + SOB were statistically at par with RDF + G₂ + SOB, RDF + G₁ + SOB and RDF + G₂ + PSB treatments. The development of a crop during vegetative stage largely defines the development of number and size of sink, which is finally the foundation of generating yield characteristics. Therefore, the yield attributing characters of a plant are highly related to growth characters developed in vegetative phase (16).

Yield attributes seems to be associated with growth parameters like dry matter production, number of branches and leaf area, which also behaved in a similar manner under different treatment. Increased number of branches may provide more points for yield attributes formation; thus, it increased the yield attributes (17, 18). Moreover, it may also be attributed to the versatile role of phosphorus in controlling photosynthesis and carbohydrates metabolism of the leaves that constitute one of the dominant plant growth, limiting factors especially through the reproductive phase and is the one that regulates the starch/sucrose ratio of the sources and the reproductive organs (19-21). The yield attributes increased with use of biofertilisers and gypsum. This might be due to higher availability of P₂O₅, Ca, S and their uptake that progressively increase photosynthesis and other physiological function of plant (22- 24).

Various important enzymes viz, dehydrogenases, phosphatases are released by the application of biofertilisers like PSBs which convert insoluble form of nutrient to soluble ones and thus make them readily available to the crops (25). These available nutrients further improve the overall growth of the plants, especially nodulation and root growth in leguminous crops. Further, nodulation is an energy consuming process, so energy is provided by ATPs which contains phosphorus (26).

Yield parameters (Grain yield, straw yield and biological yield) and protein content

It is clear from the data (Table 2) that treatments containing a higher dose of gypsum as well as 2 bioinoculants, namely RDF + G₂ + PSB + SOB, produced significantly higher seed yield (1597.67 kg/ha), straw yield (1968.20 kg/ha) and biological yield (3565.87 kg/ha) than the other treatments except RDF + G₁ + PSB + SOB which was equally effective with RDF + G₂ + PSB + SOB in obtaining yield. Significantly lower seed yield, straw yield and biological yield was recorded in alone RDF as compared to all the other treatments. The seed yield under RDF + G₂ + SOB, RDF + G₁ + SOB, RDF + G₂ + PSB and RDF + G₁ + PSB was found to be statistically at par with each. Similar results were recorded in straw yield as well as biological yield. Dual inoculation of seed with PSB and SOB has not only contributed by solubilising the applied phosphorus under tested treatments but also has made available the bound phosphorus inherited by soil through secretion of organic acids and enzymes. Instead of increased organic acids and enzyme activities, bio inoculums are also known to release plant growth promoting hormones (27). Consequences, plant experienced excellent growth resulting in more production of yield attributes and ultimately led to increased seed and straw yield of mungbean, thus enhanced biological yield (18). Effect of biofertilisers (PSB and SOB) may be due to the effect of nutrients mobilising microorganisms which might have improved nutrients availability and increased level of extractable minerals. Bacteria have been known to improve yield and its components by the production and exudation of different growth promoting substances such as phytohormones and vitamins, which led to increasing growth and ultimately crop yield (22, 28). These facts are also in agreement with previous studies (23, 24).

Table 2. Effect of PSB, sulphur oxidizing bacteria and gypsum on seed, straw, biological yield (kg/ha) and protein content in seed (%) of mungbean

| Treatments | Seed yield (kg/ha) | Straw yield (kg/ha) | Biological yield (kg/ha) | Protein content (%) |
|-------------------------------------|--------------------|---------------------|--------------------------|---------------------|
| RDF | 685.67±27.76 | 786.97±20.95 | 1472.64±48.50 | 18.17±0.44 |
| RDF + Gypsum (20 kg/ha) | 873.00±75.61 | 998.89±115.69 | 1871.89±191.30 | 20.36±0.66 |
| RDF + Gypsum (30 kg/ha) | 1004.67±33.50 | 1178.24±49.86 | 2182.91±83.27 | 20.79±0.98 |
| RDF + PSB + Gypsum (20 kg/ha) | 1188.33±74.53 | 1391.56±25.94 | 2579.89±100.32 | 22.77±0.63 |
| RDF + PSB + Gypsum (30 kg/ha) | 1219.33±35.09 | 1426.68±29.30 | 2646.01±64.31 | 23.20±0.71 |
| RDF + SOB + Gypsum (20 kg/ha) | 1284.00±19.47 | 1491.07±28.62 | 2775.07±48.08 | 23.85±0.35 |
| RDF + SOB + Gypsum (30 kg/ha) | 1296.33±54.69 | 1572.90±26.63 | 2869.23±77.81 | 24.21±0.68 |
| RDF + SOB + PSB + Gypsum (20 kg/ha) | 1476.67±41.83 | 1788.46±39.17 | 3265.12±80.76 | 26.18±0.84 |
| RDF + SOB + PSB + Gypsum (30 kg/ha) | 1597.67±97.58 | 1968.20±139.54 | 3565.87±237.11 | 26.40±0.47 |
| SEm± | 57.32 | 69.76 | 124.03 | 0.65 |
| CD (5%) | 173.32 | 210.92 | 375.05 | 1.90 |

RDF – Recommended dose of fertilizer, PSB – Phosphorus solubilising bacteria, SOB – Sulphur oxidizing bacteria

The results on the effect of various gypsum levels and biofertiliser treatments on protein content of seed in mungbean. The statistically analysed data presented in Table 2 indicated that application of RDF + G₂ + PSB + SOB registered significantly higher seed protein content (26.40 %) in mungbean and it remained at par with application of RDF + G₁ + PSB + SOB in mungbean. While significantly lower protein (18.17 %) was recorded with application of RDF: 25 N, 50 P, 25 K kg/ha which did differ significantly with all the treatments. It might be because sulphur from gypsum sulphate was continuously available to the crop at all stages of the crop growth. Thus, resulting in nitrogen availability even at the later stages through increased protein content in seed (25).

Economics

The economics of mungbean as affected by different gypsum levels and biofertiliser inoculation is presented in Table 3. It can be clearly depicted that cost of cultivation of mungbean varied from 26351 to 27901 ₹ ha⁻¹ in different treatments. Main variation in cost of cultivation is because of different gypsum levels and biofertiliser inoculation among different treatments. Data revealed that integration of higher level of gypsum with dual inoculation of biofertilisers i.e. RDF + 30 kg Gypsum/ha + PSB + SOB recorded significantly higher gross monetary advantages (117000 ₹ ha⁻¹), net monetary advantages (89099 ₹ ha⁻¹) and B: C ratio (4.19) than other treatments except RDF + 20 kg Gypsum/ha + PSB + SOB treatment. Significantly lower gross returns were recorded in RDF alone when compared with other treatments. Improvements in gross and net returns as well as B: C ratio could be attributed to lower cost of cultivation and higher phosphorus use efficiency led by biofertilisers that might be the possible cause of increase in seed and straw yield of mungbean under respective treatments. Hence, integration of gypsum with different types of biofertilisers may be considered as remunerative approach in sustaining production system. Therefore, the use of biofertilisers in crop production seems to have a special significance under concurrent situation in very high price of inorganic fertilisers. These findings are in the conformity (16, 17, 20).

Conclusion

Basis on our findings, it can be concluded that growing mungbean with gypsum and biofertilisers is most efficient proposition, when judged in terms of productivity and profitability. Biofertilisers will also improve the soil physio-chemical properties. Among treatment combinations application of RDF + 30 kg Gypsum/ha + PSB + SOB recorded maximum and significantly higher yield attributes, yields and returns of mungbean compared to rest of treatment combinations except RDF + 20 kg Gypsum/ha + PSB +

SOB, which found at par with each other. The treatment of RDF + 30 kg Gypsum/ha + PSB + SOB can be utilised by farmers for better yield and economic returns. In future, multi-location trails should be conducted to check the wider adaptability of the treatments based on the soil fertility and weather condition of the area.

Acknowledgements

Authors are thankful to Lovely Professional University, Phagwara, Punjab for providing financial support for the field experiment and inputs required for the conduct of the experiment.

Authors' contributions

VKR carried out the field experiment and data collection. RS and MC carried out the data collection, analysis and drafted the manuscript. MKS carried out the proof reading and drafting. VKS participated in the sequence alignment and data analysis. KS participated in the design of the study and performed the statistical analysis. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

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Table 3. Effect of PSB, sulphur oxidizing bacteria and gypsum on economics of mungbean

| Treatments | Gross return (₹ ha ⁻¹) | Net returns (₹ ha ⁻¹) | Cost of cultivation (₹ ha ⁻¹) | B: C ratio |
|-------------------------------------|------------------------------------|-----------------------------------|---|------------|
| RDF | 50155±2019 | 23804±2019 | 26351 | 1.90±0.08 |
| RDF + Gypsum (20 kg/ha) | 63855±5559 | 36604±5559 | 27251 | 2.34±0.21 |
| RDF + Gypsum (30 kg/ha) | 73514±2461 | 45813±2461 | 27701 | 2.65±0.09 |
| RDF + PSB + Gypsum (20 kg/ha) | 86952±5391 | 59601±5391 | 27351 | 3.18±0.20 |
| RDF + PSB + Gypsum (30 kg/ha) | 89219±2555 | 61418±2555 | 27801 | 3.21±0.09 |
| RDF + SOB + Gypsum (20 kg/ha) | 93939±1430 | 66588±1430 | 27351 | 3.43±0.05 |
| RDF + SOB + Gypsum (30 kg/ha) | 94909±3959 | 67108±3959 | 27801 | 3.41±0.14 |
| RDF + SOB + PSB + Gypsum (20 kg/ha) | 108108±3050 | 80657±3050 | 27451 | 3.94±0.11 |
| RDF + SOB + PSB + Gypsum (30 kg/ha) | 117000±7165 | 89099±7165 | 27901 | 4.19±0.26 |
| SEm± | 4190 | 4190 | - | 0.15 |
| CD (5%) | 12562 | 12562 | - | 0.43 |

RDF – Recommended dose of fertilizer, PSB – Phosphorus solubilising bacteria, SOB – Sulphur oxidizing bacteria

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Additional information

Peer review: Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

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