Annals of Plant and Soil Research 27(3): 553-557 (2025)
https://doi.org/10.47815/apsr.2025.10503

Growth, yield and quality response of soybean [*Glycine max* (L.)] to manures and biofertilizers application

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Received: September, 2025; Revised accepted: November, 2025

ABSTRACT

The present investigation entitled "Growth, yield and quality response of Soybean [Glycine max (L.)] to manures and biofertilizers application" was conducted at the Research Farm, Department of Agronomy, AKS University, Satna (M.P.) during the kharif season. The experiment was laid out in a factorial randomized block design comprising three types of manures—NADEP (7 t ha⁻¹), FYM (5 t ha⁻¹), and Vermicompost (3 t ha⁻¹)—and four types of biofertilizers—Rhizobium, PSB, KSB, and ZSB—resulting in 12 treatment combinations replicated thrice. The result revealed that all growth characters, yield, quality, and economic parameters exhibited significant improvement. Among the treatments, the application of Vermicompost @ 3 t ha⁻¹ consistently enhanced plant height, number of branches, leaves, root nodules, chlorophyll content, pods per plant, seeds per pod, yield attributes, grain yield (1362 kg ha⁻¹), oil content (21.28%), gross return (₹ 55,953.6 ha⁻¹), net return (₹ 34,618.98 ha⁻¹), and B:C ratio (1.62). Similarly, seed inoculation with Rhizobium @ 10 ml kg⁻¹ of seed also played a significant role in improving growth and yield parameters, recording the tallest plants, maximum number of branches and leaves, higher root nodules, superior chlorophyll content, greater pods per plant, highest grain yield (14.20 kg ha⁻¹) and oil content (21.92 %). However, gross return (₹55404.22/ha), net return (₹33053.77/ha) were obtained from PSB @ 40 ml/kg seed. The B:C ratio (1.48) was maximum with the application of either PSB @ 40ml Kg^{-1} of seed or ZSB 20ml Kg^{-1} of seed.Thus, the study reveals that integrated use of Vermicompost and biofertilizers, particularly Rhizobium, is highly effective in enhancing growth, yield, quality, and profitability of soybean under the given conditions.

Keywords: Biofertilizers, KSB, Manures, PSB, Rhizobium, Soybean, ZSB

INTRODUCTION

Soybean (*Glycine max* L.), which belongs to the family *Fabaceae*, is one of the important pulse and oilseed crops grown in India. Soybean is also known as 'Golden Bean'. It is a major source of vegetable protein (42%), oil (20%), and carbohydrates (21%). Soybean known for its high-value protein, oil, food, feed, and industrial application. It is among the most significant crops that can positively meet the rising global wish for food and forage. In India, the major soybean-growing states area-wise are Madhya Pradesh, Maharashtra, Rajasthan, Karnataka, and Gujarat. Madhya Pradesh's production is 51.29 lakh tonnes and stood first with 53.35 lakh ha^{-1}, followed by Maharashtra (50.72 lakh ha^{-1}), Rajasthan (11.44 lakh ha^{-1}), Karnataka (4.11 lakh ha^{-1}), Gujarat (2.66 lakh ha^{-1}), and Telangana (1.89 lakh ha^{-1}) (Anonymous, 2021). Soybean can fix atmospheric nitrogen in symbiosis with *Rhizobium* and thus has low nitrogen requirement. *Rhizobium* colonizes the roots of specific legumes to form tumor like growths called nodules which act as factories of ammonia production and phosphate solubilizing bacteria (PSB) holds the ability to convert insoluble organic/inorganic phosphate into soluble forms by secreting organic acids and influence symbiotic N fixation and could potentially be used as bio fertilizer (Chittora *et al.,* 2020). Potassium solubilizing bacteria (KSB) in known to solubilize minerals which contain K and also convert the insoluble potassium to soluble form which makes it easy for the plants to utilize them easy for their growth (Etesami*et al.,* 2015). A similar mode of action is also seen by ZSB, which helps in preventing soil damage as it makes available the organic form of minerals for the plant to consume and restricts the use of chemical fertilizers, which are not beneficial for the soil in the long term (Purwani and Ginting, 2023).

Use of organic and biofertilizers enhances crop production and sustain soil heath. In the past few decades, more attention has been given to the application of chemical, organic and bio fertilizers to boost up the crop

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production to meet the need for increasing population. The application of biofertilizer into the soil leads to increase soil fertility and crop productivity. The present need is to minimize the use of fertilizers in field crops via usage of biofertilizer, vermicompost and farmyard manure (FYM). Combination of diverse sources of nutrients (organic manure and biofertilizer) is more applicable because this lessens the use of chemical fertilizers and lessens the cost of cultivation, moreover, being an environment friendly approach (Kumar *et al.,* 2020). Many studies recommend that biofertilizers like *Rhizobium* and vermicompost alone or in mixture have shown a great promise for encouraging productivity. The biofertilizer might be anything from plant extracts to manures. Biofertilizers are materials that contain living microorganisms that penetrate the plant's rhizosphere to boost the target crop's supply or availability of primary nutrients and/or growth stimuli. There are numerous species of soil bacteria that colonize mainly in the rhizosphere of plants. *Rhizobium* belongs to family rhizobiaceae, it is the symbiotic in nature, it fixes 50-100 kg/ha^{-1} nitrogen with legumes only biofertilizers can fix atmospheric nitrogen through the process of biological nitrogen fixation (BNF) and solubilize plant nutrients like phosphates and potash; in addition, it also stimulates plant growth through the synthesis of different growth promoting substances. Bio fertilizers are products applied on the surface of a plant, seeds, or in soil and contain live microorganisms that promote plant growth and development (Wani *et al.,* 2013).

Organic manures are plant and animal wastes that are utilized to provide nutrients for plants. Organic manures contain nitrogen, phosphorus, potassium, organic carbon, enzymes, and antibiotics, which help to improve the quality and quantity of yield. Farm yard manure (FYM), vermicompost, and NADEP are the most important and widely used bulky organic manures containing 0.5:0.2:0.5%, 3.0:1.0:1.5%, and 0.5:0.5:1% average NPK, respectively. The application of farm yard manure (FYM) enhances the soil chemical and physical characteristics, which increases the soil's capacity to hold nutrients. Among large organic manures, it holds a significant place.

MATERIALS AND METHODS

The present experiment was conducted during the *Kharif* season of 2024-25 at the Research farm, Department of Agronomy, AKS University, Sherganj, Satna (M.P.). Geographically, Satna district lies in the Kymore Plateau and Satpura Hill Zone, MP-4 (Agro-climatic Zone-VIII). It is situated in the north-eastern part of Madhya Pradesh the latitude of $23^0$58' to $25^0$12' N and longitude of $80^0$21' to $81^0$23' east in Rewa division of M.P. State of India at an elevation of 315 m above mean sea level to find out the Growth, yield and quality response of Soybean [*Glycine max* (L.)] to manures and biofertilizers application.The total rainfall during the experimental period was 332.45 mm from 02 July to 07 Oct. The treatments were fitted in a Factorial Randomized Block design replicated three times thereby, making twelve treatment combinations as given T_1: (NADEP Manure @ 7 t ha^{-1} + Rhizobium 10ml Kg^{-1} of seed), T_2: (NADEP Manure@7 t ha^{-1} + PSB 40ml Kg^{-1} of seed), T_3: (NADEP Manure @ 7 t ha^{-1} + KSB 30ml Kg^{-1} of seed), T_4: (NADEP Manure @ 7 t ha^{-1} + ZSB 20ml Kg^{-1} of seed), T_5: (FYM Manure @5t ha^{-1} + Rhizobium 10ml Kg^{-1} of seed), T_6: (FYM Manure @ 5 t ha^{-1} + PSB 40ml Kg^{-1} of seed), T_7: (FYM Manure @ 5 t ha^{-1} + KSB 30ml Kg^{-1} of seed), T_8: (FYM Manure @5 t ha^{-1} + ZSB 20ml Kg^{-1} of seed), T_9: (Vermicompost Manure @ 3t ha^{-1} + Rhizobium 10ml Kg^{-1} of seed)), T_{10}: (Vermicompost Manure @ 3 t ha^{-1} + PSB 40ml Kg^{-1} of seed), T_{11}: (Vermicompost Manure @ 3 t ha^{-1} + KSB 30ml Kg^{-1} of seed), T_{12}: (Vermicompost Manure @ 3 t ha^{-1} + ZSB 20ml Kg^{-1} of seed) And there is no basal application of fertilizer to the soil . Observations on different growth and yield parameters were recorded from five randomly selectedplants in each net plot and seed yield was recorded. The harvested crop were properly dried in the sunshine before threshing. Analysis of variance approach was employed to analysed the gathered data at 5% level of significance.

RESULTS AND DISCUSSION

The outcomes of this study, together with pertinent interpretations, have been summarized as follows

Response of Manure and Biofertilizers on growth characters of soybean

The application of vermicompost @ 3t ha^{-1} in combination with Rhizobium (10 ml kg^{-1} of seed) significantly enhanced growth parameters in the crop. This integrated treatment led to a notable increase in plant height, number of branches, leaves per plant, and root nodules,

all of which contributed directly to improved grain yield. The enhanced growth can be attributed to the improved availability of macro- and micronutrients from vermicompost and the biological nitrogen fixation facilitated by Rhizobium. The presence of growth-promoting hormones such as auxins, cytokinins, and gibberellins in vermicompost may have further stimulated plant development. Maximum plant height observed under this treatment was likely due to increased nitrogen availability, which promotes cell division and elongation. The synergistic effect of organic manure and microbial inoculant created favourable soil conditions, leading to vigorous plant growth. These findings are in agreement with those reported by Machhar *et al.* (2016), Tomar *et al.* (2010), Chauhan *et al.* (2023), Kumar *et al.* (2020), Dipak *et al.* (2018), Islam *et al.* (2021), and Jaga and Sharma (2015).

Table 1: Response of manure and biofertilizers on growth characters of soybean

Treatments	Plant height (cm) 90 DAS	Number of leaves/ plant at harvest	Numberof branches/ plant at 90 DAS	Number of Root nodules per plant before flowering
Manures				
M_1	60.34	14.27	12.87	23.17
M_2	61.23	15.25	13.61	24.93
M_3	62.93	17.32	15.05	27.62
S.Em±	0.20	0.14	0.21	0.19
C.D. (*p*=0.05)	0.59	0.40	0.62	0.56
Biofertilizers				
B_1	63.93	18.40	15.66	28.60
B_2	61.88	16.44	14.04	26.76
B_3	60.78	14.87	13.51	24.44
B_4	59.41	12.73	12.16	21.16
S.Em±	0.23	0.16	0.24	0.22
C.D. (*p*=0.05)	0.68	0.46	0.71	0.64

Response of Manure and Biofertilizers on yield and yield attributing characters of soybean

The yield-contributing traits of soybean were significantly influenced by the application of higher nutrient levels, particularly the combined use of vermicompost @ 3 t ha^{-1} and Rhizobium @ 10 ml kg^{-1} of seed. This treatment recorded the maximum number of pods per plant, seeds per pod, grain yield, stover yield/plotand test weight. The improved yield attributes can be directly linked to enhanced vegetative growth, likely driven by the increased availability of essential nutrients and growth-promoting substances, along with better root development and nutrient absorption.

The continuous nutrient supply ensured by vermicompost mineralization, coupled with the early-stage benefits of Rhizobium, supported plant growth across all phenological stages. Efficient translocation of photosynthates to reproductive organs contributed to increased seed development and grain filling. The synergistic effect of organic manure and biofertilizer created favarable soil conditions, enhancing nutrient uptake and biomass accumulation. Consequently, there was a notable increase in , stover yield per plot (kg), grain yield (kg ha^{-1}), and total biological yield.These results underscore the potential of integrated nutrient management in soybean cultivation and align with the findings reported by Singh *et al.* (2007), Chavan *et al.* (2008), Patra *et al.* (2012), and Singh *et al.* (2011).

Response of Manure and Biofertilizers on quality character of soybean

The oil content of soybean was notably influenced by the application of different organic nutrient sources, with the highest oil percentage recorded under the application of vermicompost @ 3 t ha^{-1}. This increase in oil contentmay be attributed to the improved nitrogen availability, which enhances protein synthesis within the seed. Elevated protein levels may, however, reduce the availability of carbohydrates required for conversion into acetyl Co-A, a key precursor in fatty acid biosynthesis. As reported by Mekki and Ahmed (2005), such a shift in nitrogen levels may alter the metabolic balance between protein and carbohydrate pathways, thereby influencing the oil synthesis potential of the seed. Thus, the higher oil content observed under vermicompost application suggests a complex interaction between nutrient availability and seed metabolic activity.

Table 2: Effect of manures and biofertilizers on yield and yield attributes of soybean

Treatments	Number of pods / plant	Number of seeds / pod	Test weight	Grain yield	Stover yield	Oil content (%)
Manures						
M_1	43.82	1.48	137.25	1277	24.09	19.74
M_2	44.82	2.03	144.83	1303	21.92	20.45
M_3	47.02	2.30	157.21	1362	25.27	21.28
S.Em±	0.29	0.14	1.25	12	0.69	0.20
C.D. (*p*=0.05)	0.86	0.42	3.66	36	2.03	0.59
Biofertilizers						
B_1	48.24	3.09	161.33	1420	27.75	21.92
B_2	46.38	1.73	152.92	1350	26.17	20.74
B_3	44.20	1.56	140.56	1291	22.18	20.12
B_4	42.04	1.38	130.90	1195	18.95	19.18
S.Em±	0.34	0.17	1.44	14	0.80	0.23
C.D. (*p*=0.05)	1.00	0.49	4.23	36	2.35	0.68

Response of Manure and Biofertilizers on economics

The economic assessment of soybean production, as assessed by gross monetary returns, net monetary returns (NMR), and benefit-cost (B: C) ratio, demonstrated variability due to varying nutrient levels during the experimental year. Among the different fertility levels, the application of vermicompost @ 3 t ha^{-1}combined with KSB(30ml Kg^{-1} of seed) emerged as the most financially rewarding approach for soybean cultivation. Net returns are derived bymultiplying grain and straw yields by their respective market prices and then subtracting the total cost of cultivation, including treatmentspecific expenses. The fluctuations in NMR were primarily attributed to differences in the crop's yield (both grains and straw). The highest GMR, NMR and B:C ratio observed under the treatment involving vermicompost @ 3 t ha^{-1}combined with KSB(30ml Kg^{-1} of seed) could be attributed to relatively lower additional costs compared to other treatments. This favorable B:C ratio is linked to higher yield under higher nutrient concentrations as opposed to the lower concentration of other nutrient levels. Comparable findings were reported by Sarawgi *et al.,* (2012), Chauhan *et al.,* (2023), Awasthi *et al.,* (2020) and Machhar *et al.* (2016).

Table 3: Effect of biofertilizers and varieties on economics of soybean

Treatments	Cost of cultivation (₹ ha^{-1})	Gross monetary returns (₹ ha^{-1})	Net monetary returns (₹ ha^{-1})	Benefit: Cost ratio
Manures				
M_1	22734.6	53786.0	31051.38	1.37
M_2	22734.6	55065.5	32330.90	1.42
M_3	21334.6	55953.6	34618.98	1.62
S.Em±	--	582.81	582.81	0.03
C.D. (*p*=0.05)	--	1709.33	1709.33	NS
Biofertilizers				
B_1	22230.43	54916.78	32686.33	1.47
B_2	22350.43	55404.22	33053.77	1.48
B_3	22290.43	54190.89	31900.47	1.44
B_4	22200.43	55228.22	33027.77	1.48
S.Em±	--	504.73	504.73	0.02
C.D. (*p*=0.05)	--	1480.33	1480.33	0.07

M_1: NADEP 7t ha^{-1},M_2:FYM 5t ha^{-1},M_3: Vermicompost 3t ha^{-1},B_1: Rhizobium @ 10 ml kg^{-1} seed, B_2: PSB @ 40 ml kg^{-1} seed, B_3: KSB @ 30 ml kg^{-1} seed, B_4: ZSB @ 20 ml kg^{-1} seed

CONCLUSION

On the present study, it can be concluded that the combined application of vermicompost @ 3 t ha^{-1} and Rhizobium @ 10 ml kg^{-1} of seed significantly enhanced seed yield, oil content, gross and net monetary returns, and the benefit-cost (B:C) ratio in

soybean cultivation. This integrated nutrient management approach appears to be a promising and economically viable strategy for maximizing productivity and profitability in soybean farming. However, as the conclusions are drawn from a single-season experiment, further multi-season and multi-location trials are recommended to validate and generalize the results under diverse agro-climatic conditions.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the support and facilities provided by AKS University, Satna, for conducting this research. Special thanks to Dr. T. Singh, Senior ProfessorAKS University, Satna, for his valuable guidance and constructive suggestions throughout the study.

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