



International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X
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NAAS Rating (2026): 5.20
www.agronomyjournals.com
2026; 9(4): 37-41
Received: 02-02-2026
Accepted: 04-03-2026

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Impact of conjunctive use of organic manure, chemical fertilizers and seed bio-priming on growth and yield of lentil crop (*Lens culinaris* M.)

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DOI: <https://www.doi.org/10.33545/2618060X.2026.v9.i4a.5326>

Abstract

A field experiment was conducted during *rabi* seasons of 2021 and 2023 at the Agricultural Research Farm of Shri Murl Manohar Town Post Graduate College, Ballia, Uttar Pradesh, entitled the effect of integrated nutrient management and seed bio-priming on growth, yield, quality of lentil (*Lens culinaris* M.), and fertility status of alluvial soil. The experiment comprised eleven treatments involving combinations of recommended NPK, organic amendments (vermicompost, press mud, and fly ash), seed bio-priming with Rhizobium and PSB, and foliar application of boron (0.2% and 0.5%) at flowering stage, laid out in a randomized block design. The growth parameters including seedling dry weight, plant height, primary and secondary branch, number of leaves, number of pods, grain, stover and biological yield attributes were recorded at 90 DAS. Results indicated that integrated use of 75% NPK combined with organic amendments, seed bio-priming, and boron spray significantly improved plant growth, yield attributes, and seed yield compared to control and sole chemical fertilization. Treatments receiving vermicompost along with bio-priming and boron spray showed superior performance, indicating enhanced nutrient availability and better soil fertility status. Overall, integrated nutrient management coupled with seed bio-priming and boron application proved effective in improving productivity and sustainability of lentil cultivation under alluvial soil conditions of eastern Uttar Pradesh.

Keywords: Integrated nutrient management, Seed bio-priming, Boron application, Lentil (*Lens culinaris* M.), Vermicompost, Soil fertility, Yield attributes

Introduction

Lentils (*Lens culinaris* M.) are a member of the Leguminosae family and are considered pulse crops. Among the most seasoned and nourishing crops cultivated during the *rabi* season. To a large degree, it can withstand harsh winters and frost. It needs cold temperatures when growing vegetatively and warm temperatures (18 to 30°C) when it reaches maturity. Additionally, lentils display better adaptability to low-water soil conditions, requiring less water and demonstrating increased resilience to drought stress compared to other crops (Sehgal *et al.*, 2021) [6]. In India, lentil seeds are referred to as "the poor man's meat" and "masoor" due to its great nutritional value, which includes fiber, carbohydrates, vitamins A and B, potassium, iron, and low amounts of fat and salt. Mainly eaten as dry seeds, it is a good diet for humans. Lentils are one of the most important edible grain legumes in terms of a balanced and healthy diet. Namba- Santiago *et al.* (2023) [5] suggested that the grain of lentils is rich in protein, vitamins, fiber and minerals. Lentil leaves a N-rich soil for the crop planted after it via biological N fixation; however, root nutrients such as N, Ca, P, and K remain in the soil root zone as a result of decomposition (Ahmad *et al.*, 2022) [1]. For sustainable agriculture, the amount of organic matter is important for soil fertility, protection, and sustainability. With a 44% and 18% share of global production, respectively, Canada dominates global lentil production, followed closely by India (Food and Agriculture Organization, 2021). The data from 2021-22 reveals that Rajasthan holds the top position as the leading pulse producer in India, boasting an annual production of 4364.74 tonnes. Organic manure promotes microorganism those are beneficial to plant growth because they fix certain nutrients, which lasts in soil until consumed by the plants. The organic manures, improves the organic carbon in soil on its application (Khan *et al.*, 2010).

Organic carbon performs additional functions of increasing soil organic matter content, and CEC, enhance biological activity, improves soil structure (Uwah and Iwo, 2011). Low productivity of lentil may be ascribed to many reasons such as inadequate and imbalanced fertilization and prevalence of suboptimum soil moisture condition. The lentil crop shows good response to phosphorus fertilization (Muhammad *et al.*, 2002) [4]. Rhizobium and phosphate solubilizing bacteria are known to enhance the productivity of the crop as they increase the availability of soil nitrogen and phosphorus (Elsayed, 1999). Phosphorus is one of the macronutrients required for biological growth and development. Among the major nutrients phosphorus is considered to be one of the major limiting nutrient elements in pulse production in India, particularly in acid soils of North Eastern India, including Manipur. Phosphorus plays a vital role in cultivation of legumes as it directly enhances grain formation, stimulates early formation and growth of roots, improves nodulation, seed yield and seed crude protein content (Singh *et al.*, 2014) [7]. Bio-priming of seed is a wonderful approach to meet the demand of chemical free food for ever increasing population. Bio-priming of seed uses microbial inoculants of plant growth promoting rhizobacteria and fungi. It is an eco-friendly strategy using selected microorganism which produces substances for growth promotion and pathogen inhibition. Presently, seed treatment with biological inoculants is being used as a substitute to synthetic chemical pesticides and fertilizers in agriculture for plant and soil health improvement. Using biocontrol agents with priming agents for seed treatment over simple seed coating has potential advantages and serves as a better strategy of managing many seed and soil-borne diseases. In this study, our main objective was to contribute to the sustainable agricultural production of our region in particular, and our country in general, with practices that are more protective of human health than chemical fertilizer applications, by capturing the benefits of organic fertilization in our region.

Materials and Methods

Experimental Site and Duration

The field experiments were conducted during the *Rabi* seasons of 2021-2022 and 2022-2023 at the Nidharia, Agricultural Research Farm, Shri Murli Manohar Town P.G. College, Ballia, Uttar Pradesh, India. The experimental site is located at 25°0.76' N latitude and 84°0.12' E longitude, at an altitude of 59 m above mean sea level. The region falls under a sub-tropical climate, with hot summers and cool winters. The average annual rainfall of the district is about 648 mm, mostly received during July to September.

Experimental Design and Treatments

The experiment was laid out in a Randomized Block Design (RBD) with 11 treatments and three replications. Each plot measured 5.0 m × 3.0 m. The treatments consisted of different combinations of recommended dose of fertilizers (RDF), organic manures, seed bio-priming with plant growth-promoting rhizobacteria (PGPR), and boron spray.

Crop Variety and Sowing

The lentil variety Pusa L-4717 was used in both seasons. Seeds were sown at a rate of 30 kg ha⁻¹, maintaining a spacing of 30 cm × 10 cm with a sowing depth of 3-5 cm. Sowing was done manually using a khurpi.

Treatment Details

- T₁: Control

- T₂: 100% RDF
 - T₃: 75% RDF + Vermicompost @ 5 t ha⁻¹
 - T₄: 75% RDF + Press mud @ 5 t ha⁻¹
 - T₅: 75% RDF + Fly ash @ 5 t ha⁻¹
 - T₆: T₃ + Seed bio-priming with PGPR + 0.2% B spray at flowering
 - T₇: T₄ + Seed bio-priming with PGPR + 0.2% B spray at flowering
 - T₈: T₅ + Seed bio-priming with PGPR + 0.2% B spray at flowering
 - T₉: T₃ + Seed bio-priming with PGPR + 0.5% B spray at flowering
 - T₁₀: T₄ + Seed bio-priming with PGPR + 0.5% B spray at flowering
 - T₁₁: T₅ + Seed bio-priming with PGPR + 0.5% B spray at flowering
- The recommended fertilizer dose for lentil was 20:40:20 kg N:P₂O₅:K₂O ha⁻¹.

Application of Organic Manures and Fertilizers

Organic manures (vermicompost, press mud, and fly ash) and chemical fertilizers were applied three days before sowing as per treatment schedule. Representative samples of organic manures were analyzed for their nutrient content to ensure precise nutrient application.

Seed Bio-Priming

Seed bio-priming was carried out for treatments T₆ to T₁₁ using Rhizobium culture (10 g kg⁻¹ seed) and phosphate-solubilizing bacteria (PSB) (10 g kg⁻¹ seed). The treated seeds were shade-dried and sown immediately. Bio-priming was done to enhance seed germination, root nodulation, and early crop vigor.

Growth Parameter

- Germination%
- Dry matter of seedling
- Plant height (90 DAS)
- Number of branches (primary and secondary branches) (90 DAS)
- Number of leaves (90 DAS)

Yield

- Number of pods plant⁻¹
- Filled and unfilled pods
- Pod length and width
- Grain yield, stover yield, and biological yield
- Grain and stover yields were recorded on a plot basis and converted to kg ha⁻¹.

Grain and stover samples were oven-dried, ground, and analyzed for N, P, K, and S using standard digestion and estimation techniques.

Results and Discussion

Effect of Treatments on Germination and Seedling Growth

The results revealed that germination percentage and early seedling growth parameters were significantly influenced by the integrated use of organic manures, chemical fertilizers, seed bio-priming (Table 1). Among the treatments, seed bio-priming with *Rhizobium* and PSB in combination with organic amendments

recorded higher germination percentage compared to control and sole RDF treatment.

Vermicompost + seed-biopriming recorded the maximum germination percentage. Improved germination may be attributed to enhanced microbial activity, better nutrient solubilization, and production of growth-promoting substances by PGPR during early growth stages. Similar findings were

reported by Elsayed (1999) and Singh *et al.* (2014)^[7] in lentil.

Seedling dry matter accumulation was significantly higher in integrated treatments 75% RDF + Vermicompost @ 5 t + ha⁻¹ Seed bio-priming with PGPR + 0.5% B spray (T₉) at flowering and (T₆). The increase in dry matter might be due to improved nutrient availability and better root development under integrated nutrient management.

Table 1: Effect of treatments on germination

Treatment	Germination percentage of seed	
	2021-2022	2022-2023
Control	89.98	90.19
Inorganic, vermicompost and seed bio- priming	94.24	93.74
Inorganic, press-mud and seed bio- priming	91.98	92.23
Inorganic, fly ash + seed bio- priming	90.37	91.40

Table 2: Effect of treatments on seedling growth

Treatment	Seedling dry weight (mg)	
	2021-2022	2022-2023
T ₁	19.34	19.35
T ₂	19.77	19.79
T ₃	19.62	19.64
T ₄	19.51	19.53
T ₅	19.43	19.45
T ₆	19.79	19.82
T ₇	19.71	19.73
T ₈	19.48	19.49
T ₉	19.80	19.82
T ₁₀	19.73	19.74
T ₁₁	19.50	19.51
SEm±	0.02	0.01
CD (P=0.05)	0.06	0.04

Effect on Plant Height, Branching, and Number of Leaves

Plant height, number of primary and secondary branches, and number of leaves at 90 DAS were significantly influenced by different treatments (Table 3). Integrated application of 75% RDF with organic manures and seed bio-priming resulted in higher vegetative growth compared to sole application of chemical fertilizers.

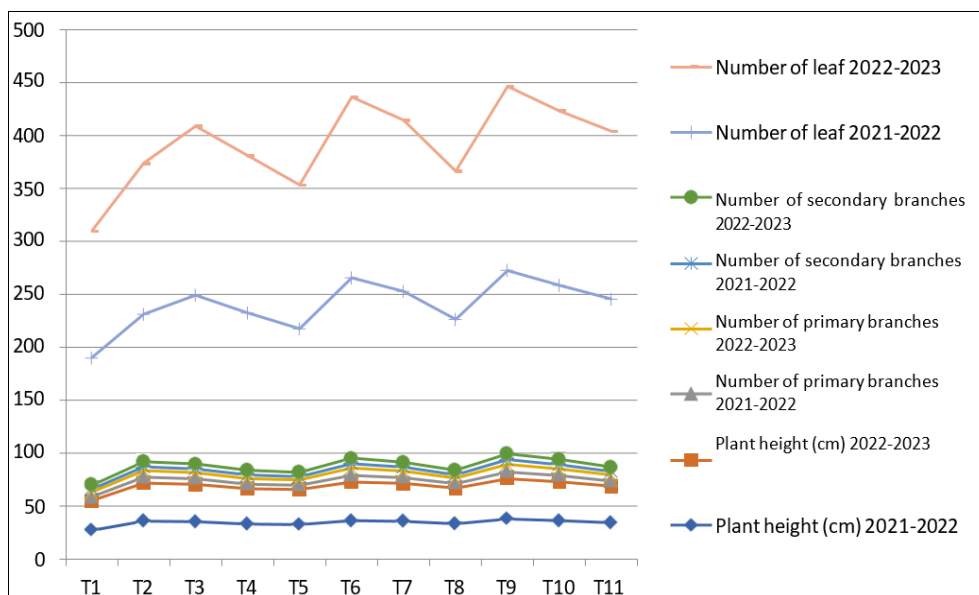
Maximum plant height was recorded under 75% RDF + Vermicompost @ 5 t + ha⁻¹ Seed bio- priming with PGPR + 0.5% B spray T₉, followed by T₆ and T₁₀. Vermicompost-based

treatments consistently performed better than press mud and fly ash treatments. This may be due to the gradual release of nutrients, improvement in soil structure, and enhanced microbial activity associated with vermicompost application (Khan *et al.*, 2010; Uwah and Iwo, 2011).

Seed bio-priming with *Rhizobium* and PSB significantly increased the number of branches, which might be attributed to better nodulation, nitrogen fixation, and phosphorus availability. Boron spray further enhanced cell division and elongation, leading to improved vegetative growth.

Table 3: Effect of treatments on plant height, branches, and number of leaves at 90 DAS

Treatment	Plant height (cm)		Number of primary branches		Number of Secondary branch		Number of leaf	
	2021-2022	2022-2023	2021-2022	2022-2023	2021-2022	2022-2023	2021-2022	2022-2023
T ₁	27.41	27.46	4.13	4.20	3.33	3.40	119.67	119.80
T ₂	35.88	35.91	5.80	5.87	4.07	4.13	139.27	142.73
T ₃	35.29	35.32	5.47	5.53	3.93	4.07	159.33	159.60
T ₄	33.12	33.13	4.80	4.87	3.93	3.93	148.47	148.60
T ₅	32.71	32.77	4.53	4.60	3.53	3.60	135.40	135.73
T ₆	36.36	36.44	6.53	6.60	4.60	4.67	170.13	170.73
T ₇	35.65	35.74	5.80	5.87	4.07	4.13	161.27	161.80
T ₈	33.43	33.48	4.67	4.73	3.67	3.73	142.40	139.80
T ₉	37.98	38.07	6.73	6.80	4.80	4.87	173.20	173.80
T ₁₀	36.42	36.51	6.07	6.13	4.33	4.40	164.27	164.73
T ₁₁	34.39	34.45	5.20	5.27	3.73	3.80	158.33	158.47
SEm±	0.26	0.28	0.07	0.07	0.08	0.05	0.09	0.10
CD (P=0.05)	0.77	0.85	0.21	0.20	0.23	0.15	0.25	0.30



Graph 1: Effect of treatments on plant height, branches, and number of leaves at 90 DAS

Effect on Yield Attributes

Yield-attributing characters such as number of pods plant⁻¹, number of filled pods, pod length, and pod width were significantly affected by different treatments (Table 4). Integrated nutrient management treatments outperformed control and RDF-only treatments.

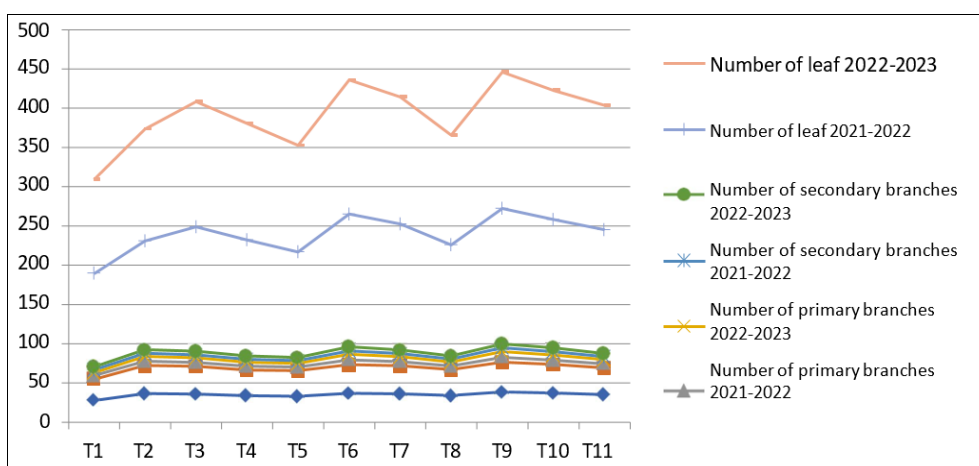
The highest number of pods plant⁻¹ and filled pods was observed under T₉, followed by T₆ and T₁₀. The improvement in yield

attributes may be attributed to enhanced nutrient uptake, balanced nutrition, and better translocation of assimilates due to boron application at flowering stage.

Boron plays a vital role in pollen viability, flower retention, and pod formation. The superior performance of boron-applied treatments supports earlier findings that boron application enhances reproductive growth and seed setting in pulses (Singh *et al.*, 2014)^[7].

Table 4: Effect of treatments on yield attributes of lentil

Treatment	Number of pods		Number of filled pods		Number of empty pods		Pod length(mm)		Pod width (mm)	
	2021-2022	2022-2023	2021-2022	2022-2023	2021-2022	2022-2023	2021-2022	2022-2023	2021-2022	2022-2023
T ₁	103.40	108.20	84.60	89.00	18.80	19.20	10.05	10.09	6.47	6.63
T ₂	112.60	113.80	98.40	95.70	14.20	14.80	10.41	10.46	8.56	8.61
T ₃	119.80	122.40	107.20	109.20	12.60	13.20	11.09	11.29	8.97	9.03
T ₄	115.20	118.80	101.80	104.40	13.40	14.40	10.54	10.62	8.64	8.93
T ₅	108.80	112.40	93.40	96.20	15.40	16.20	10.28	10.31	8.45	8.52
T ₆	125.60	131.20	114.40	117.60	11.20	13.60	11.30	11.36	9.78	9.87
T ₇	120.80	124.60	108.00	110.80	12.80	13.80	10.58	10.62	9.62	9.66
T ₈	113.40	115.80	99.40	101.60	14.00	14.20	10.51	10.59	8.80	8.89
T ₉	131.20	137.60	120.40	126.40	10.80	11.20	11.38	11.59	9.96	10.20
T ₁₀	127.60	132.80	115.60	119.60	12.00	13.20	10.73	10.77	9.73	9.99
T ₁₁	118.40	120.40	104.60	105.60	13.80	14.80	10.54	10.64	9.07	9.17
SE _{em} ±	0.03	0.38	0.05	1.06	0.06	0.02	0.24	0.23	0.04	0.05
CD (P=0.05)	0.09	1.11	0.14	3.12	0.18	0.06	0.71	0.69	0.11	0.14



Graph 2: Effect of treatments on yield attributes of lentil

Effect on Grain Yield, Stover Yield, and Biological Yield

Grain yield, stover yield, and biological yield were significantly influenced by integrated nutrient management practices (Table 5). The highest grain yield was recorded under T₉, which was statistically superior to control and 100% RDF but at par with T₆.

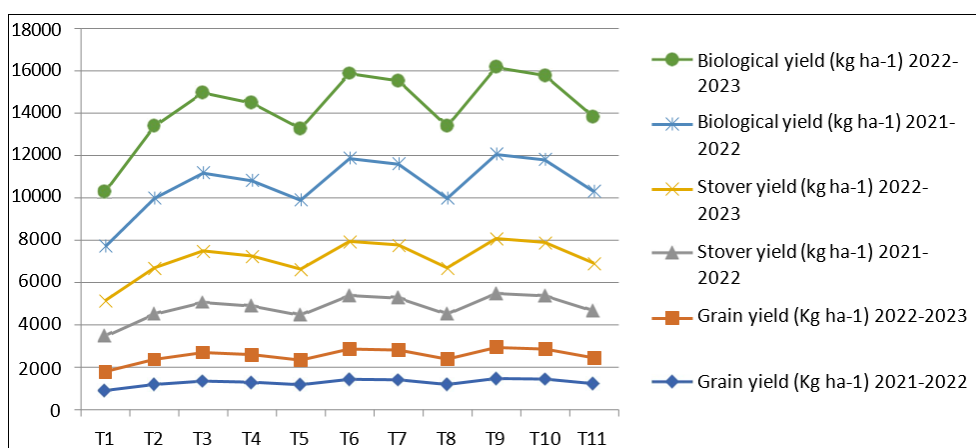
Compared to control, grain yield increased substantially under integrated treatments, indicating the positive role of organic

manures and bio-priming in sustaining crop productivity. Vermicompost-based treatments recorded higher yields than press mud and fly ash, possibly due to better nutrient synchrony and improved soil physical properties.

Stover and biological yields followed a similar trend, suggesting that integrated nutrient management improved overall biomass production. Reduction of chemical fertilizers by 25% without yield penalty highlights the sustainability of the approach.

Table 5: Effect of treatments on grain yield, stover yield, and biological yield

Treatment	Grain yield (Kg ha ⁻¹)		Stover yield (kg ha ⁻¹)		Biological yield (kg ha ⁻¹)	
	2021-2022	2022-2023	2021-2022	2022-2023	2021-2022	2022-2023
T ₁	903.13	910.37	1661.59	1681.26	2564.72	2591.63
T ₂	1177.80	1212.13	2120.04	2180.17	3297.84	3392.30
T ₃	1340.28	1374.59	2358.89	2414.28	3699.17	3788.87
T ₄	1292.83	1324.15	2288.31	2340.41	3581.14	3664.55
T ₅	1161.78	1192.11	2114.44	2166.31	3276.22	3358.42
T ₆	1425.37	1463.31	2507.33	2546.01	3932.7	4009.32
T ₇	1402.37	1432.033	2440.12	2494.26	3842.49	3926.30
T ₈	1183.21	1217.20	2117.77	2173.10	3300.98	3390.30
T ₉	1462.34	1503.01	2529.85	2591.52	3992.19	4094.53
T ₁₀	1437.27	1456.94	2489.07	2515.19	3926.34	3972.13
T ₁₁	1215.98	1253.31	2192.33	2245.76	3408.31	3499.07
SEm±	4.30	4.26	14.15	6.18	18.14	6.78
CD (P=0.05)	12.70	12.57	43.82	18.23	53.52	20



Graph 3: Effect of treatments on grain yield, stover yield, and biological yield

Conclusion

The results clearly demonstrated that conjunctive use of organic manures, chemical fertilizers and seed bio-priming significantly improved growth, yield attributes, and yield of lentil. The superiority of vermicompost-based treatments indicates its effectiveness in improving nutrient availability and soil health. Reduction of chemical fertilizers by 25% along with organic and biological inputs not only maintained yield but also improved soil fertility, making the production system more sustainable. These findings are in agreement with earlier reports emphasizing the role of integrated nutrient management in pulse crops.

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