

RESEARCH PAPER

# Micronutrient-Enriched NPK Fertilization Enhances Yield and Profitability of Green Gram Under Middle Gangetic Plain

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## ABSTRACT

Mung bean (*Vigna radiata* L. Wilczek) plays a vital role in enhancing food security and soil fertility within cereal-based cropping systems of Eastern Uttar Pradesh. Despite its agronomic potential, yield stagnation persists due to suboptimal nutrient management. A field experiment conducted during *Kharif* 2023–24 at the Agricultural Research Farm, BHU, evaluated six nutrient management treatments under a randomized block design to assess their impact on mung bean productivity and profitability. The integration of 100% Recommended Dose of Fertilizers (RDF) through specialized NPK pulse fertilizer (14:35:14) supplemented with MOP and urea (T3) recorded the highest seed yield (2.24 t ha<sup>-1</sup>), biological yield (5.58 t ha<sup>-1</sup>), and harvest index (38.4%). Economic analysis revealed T3 as the most viable option, achieving the highest net return (₹ 1,59,071.54 ha<sup>-1</sup>) and benefit-cost ratio (3.27). The superior performance is attributed to balanced macro- and micronutrient availability, enhanced nodulation, and improved physiological efficiency. These findings underscore the importance of micronutrient-enriched fertilizer strategies for sustainable mung bean intensification in the Indo-Gangetic Plains.

## HIGHLIGHTS


- Balanced NPK pulse fertilizer enriched with Zn, B, and Mo significantly enhanced mung bean yield and physiology, with treatments T3 (100% RDF) and T5 (125% RDF) recording the highest seed yield (2.24 t ha<sup>-1</sup>), biological yield (~5.6 t ha<sup>-1</sup>), and superior harvest indices.
- Economic analysis revealed T3 as the most cost-effective treatment, achieving the highest net return (1,59,071.54 ha<sup>-1</sup>), benefit-cost ratio (3.27), and ROI (2.27), thereby outperforming conventional fertilization practices despite comparable productivity with T5.
- Micronutrient-enriched fertilization strategies improved nodulation, nitrogen fixation, and resource-use efficiency, underscoring their role in sustainable intensification of pulse-based systems in the Indo-Gangetic Plains while bridging yield gaps and strengthening food security.

**Keywords:** Mung bean, NPK Pulse Fertilizer, RDF Levels, Micronutrient Enrichment (Zn, B, Mo), Benefit-Cost Ratio, Return on Investment, Integrated Nutrient Management, Soil Fertility and Nutrient Uptake

Mung bean (*Vigna radiata* L. Wilczek) is a short-duration pulse crop of major importance across South and Southeast Asia, particularly India, where it contributes significantly to both nutrition and agriculture (Idris *et al.* 2025). Its seeds contain ~25–26% high-quality protein—double that of wheat and triple that of rice—alongside 55–60%

carbohydrates and essential amino acids such as lysine and tryptophan, making it a vital dietary

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source in vegetarian populations (Shiksha *et al.* 2025). High digestibility further enhances its value for children, the elderly, and convalescents.

Beyond food security, mung bean supports sustainable farming systems as green manure, intercrop, and livestock fodder, improving soil fertility through symbiotic nitrogen fixation. Fixation levels range from 30 to 251 kg N ha<sup>-1</sup>, with an average contribution of ~34 kg N ha<sup>-1</sup>, boosting subsequent cereal yields by 30–350% (Maqsood *et al.* 2001; Ali & Kumar, 2005). Despite cultivation on 5.18 million hectares and production of 3.10 million tonnes, India's average yield (~400–500 kg ha<sup>-1</sup>) remains far below its genetic potential (1.8–2.5 t ha<sup>-1</sup>) (Shiksha *et al.* 2025). Rajasthan dominates in acreage but faces productivity constraints under low-input, arid conditions, while irrigated states like Tamil Nadu achieve relatively higher yields (Sharan *et al.* 2020; ICAR-IIPR, 2022).

Persistent yield gaps stem largely from imbalanced fertilization and poor nutrient management. Although pulses demand fewer external inputs than cereals, mung bean productivity requires balanced application of macronutrients (N, P, K) along with secondary and micronutrients such as sulfur (S), zinc (Zn), molybdenum (Mo), cobalt (Co), and iron (Fe) (Yin *et al.* 2018). To address this, Coromandel International's new NPK Pulse Fertilizer (14:35:14 enriched with 0.5% Zn, 0.2% B, and 0.01% Mo) was evaluated against conventional fertilization practices (DAP + MOP + urea) and GroShakti-based treatments at varying RDF levels (75%, 100%, 125%) under Eastern Uttar Pradesh conditions.

## MATERIALS AND METHODS

The field experiment was conducted during the *Kharif* season of 2023–24 at the Agricultural Research Farm of the Institute of Agricultural Sciences, Banaras Hindu University (BHU), Varanasi, Uttar Pradesh, India (25°15'50" N, 82°59'22" E; elevation 146 m above mean sea level). Varanasi lies at an altitude of 80.71 m above mean sea level, between 25°18' N latitude and 80°36' E longitude. The region's climate is classified as semi-arid to sub-humid, with a moisture deficit index of 20–40. Relative humidity averages ~68% during the wet season and ~82% during the dry season, while temperatures range from 9°C to 42°C annually. The soil of the experimental plot was Sandy clay loam,

Prior to the field investigation, a soil sample was examined, and EC, pH, organic carbon, available N, available P, and available K values were recorded as 0.10 dS m<sup>-1</sup>, 7.8, 0.68%, 142.7 kg ha<sup>-1</sup>, 15.1 kg ha<sup>-1</sup>, and 128 kg ha<sup>-1</sup>, respectively. The land was ploughed and harrowed thoroughly, followed by pre-sowing irrigation to ensure proper germination and crop establishment. Seedbeds were prepared with appropriate spacing. The mung bean variety Malavya 16 (MH-16), developed by the Institute of Agricultural Sciences, BHU, was used. This variety matures in 50–60 days, has an erect plant habit (40–50 cm height), green stems, broad green leaves, yellow flowers, and black mature pods. Seeds are green and dull, with a 1000-seed weight of 40 g. Sowing was carried out on 17 July 2023 using the line sowing method at a seed rate of 20 kg ha<sup>-1</sup>. Fertilizers were applied basally according to treatment specifications, placed below the seeds at sowing.

The experiment comprises of six treatment each having three replication are as follows: -T<sub>1</sub>: 100% RDF (DAP + MOP + Urea), T<sub>2</sub>: 100% RDF of Groshakti + MOP + Urea, T<sub>3</sub>: 100% RDF of NPK pulse + MOP + Urea, T<sub>4</sub>: 75% RDF of NPK pulse + MOP + Urea, T<sub>5</sub>: 125% RDF of NPK pulse + MOP + Urea, T<sub>6</sub>: Absolute control. All the agronomic practices were carried out uniformly to raised the crop. For taking data on yield and yield components on mung bean five plants were selected randomly in each plot and averaged. The harvested crop plants from the net plots were bundled and sundried plot-wise, the biological yield was calculated by converting the bundle weight into tons per hectare. To calculate grain yield (tha<sup>-1</sup>) the total weight of grains obtained from the net plot area was recorded at 9 percent grain moisture. The yield per plot was converted into tons per hectare. The moisture was determined by the moisture meter. Similarly the straw yield (t ha<sup>-1</sup>) was calculated by subtracting the grain yield from the total produce of each plot and was converted into tons per hectare. The recovery of grains from the total dry matter was considered as Harvest Index (H.I.) which is expressed in percentage. It was calculated by the following formula:

$$\text{Harvest Index (\%)} = (\text{Grain Yield} / \text{Biological Yield}) \times 100$$

## Economic Analysis

Economic evaluation of each treatment was conducted using standard metrics—cost of cultivation, gross return, net return, benefit-cost ratio (BCR), and return on investment (ROI)—based on prevailing market prices of inputs and outputs.

### Cost of Cultivation (₹ ha<sup>-1</sup>)

The cost of cultivation was calculated separately for each treatment, factoring in all cultural operations and input costs relevant to the crop cycle.

### Gross Return (₹ ha<sup>-1</sup>)

Gross return was derived by aggregating revenue from grain and stover yield:

$$\text{Gross Return} = \text{Grain Income} + \text{Stover Income}$$

### Net Return (₹ ha<sup>-1</sup>)

Net return represents the profit margin from each treatment, calculated as:

$$\text{Net Return} = \text{Gross Return} - \text{Cost of Cultivation}$$

### Benefit-Cost Ratio (BCR)

To assess cost-effectiveness, the BCR was computed using:

$$\text{BCR} = \text{Net Return} / \text{Cost of Cultivation} \text{ (Garg et al. 2024)}$$

### Return on Investment (ROI)

ROI was estimated to determine investment efficiency across treatments:

$$\text{ROI} = \text{Net Return} / \text{Total Expenditure} \text{ (Garg et al. 2024)}$$

## STATISTICAL ANALYSIS

All experimental data were subjected to one-way ANOVA, and treatment means were compared using Duncan's Multiple Range Test (DMRT) at a significance level of  $P \leq 0.05$ . Microsoft Excel was used for all statistical computations.

## RESULTS AND DISCUSSION

### Effect on yield and yield attributes

Table 1 reveals that the maximum values for yield and yield-contributing traits—number of seeds per pod, test weight (g), seed yield, biological yield, stover yield, and harvest index—were recorded in T3 (100% RDF of NPK pulse fertilizer + urea + MOP) and T5 (125% RDF of NPK pulse fertilizer + urea + MOP), which are statistically comparable. These were followed by T2 (100% RDF of Groshakti + MOP + urea), T1 (100% RDF through DAP + MOP + urea), and T4 (75% RDF of NPK pulse fertilizer + urea + MOP), with the lowest values observed in the absolute control (T6).

The superior performance of T5 and T3 treatments is attributed to enhanced chlorophyll content, leaf area, and leaf number, leading to improved photosynthetic efficiency. This physiological advancement supports vigorous flowering and fruiting, backed by optimal nutrient availability and uptake. The balanced nutrient application enhances soil water-holding capacity, promotes physical

**Table 1:** Effect of NPK fertiliser on different yield attributes

Treatments	No. of seeds per pod	Test weight (gm)	Seed yield (tha <sup>-1</sup> )	Stover yield (tha <sup>-1</sup> )	Biological Yield (tha <sup>-1</sup> )	Harvesting Index (%)
T <sub>1</sub> : 100% RDF (DAP + MOP + Urea)	10.00 <sup>c</sup>	42.95 <sup>b</sup>	2.05 <sup>b</sup>	3.16 <sup>b</sup>	5.18 <sup>b</sup>	37.2 <sup>c</sup>
T <sub>2</sub> : 100% RDF of Groshakti + MOP + Urea	9.80 <sup>d</sup>	42.31 <sup>c</sup>	2.04 <sup>b</sup>	3.08 <sup>cd</sup>	5.09 <sup>b</sup>	36.9 <sup>d</sup>
T <sub>3</sub> : 100% RDF of NPK pulse + MOP + Urea	11.23 <sup>b</sup>	45.48 <sup>a</sup>	2.24 <sup>a</sup>	3.40 <sup>a</sup>	5.58 <sup>a</sup>	38.4 <sup>b</sup>
T <sub>4</sub> : 75% RDF of NPK pulse + MOP + Urea	9.73 <sup>d</sup>	41.44 <sup>d</sup>	1.91 <sup>c</sup>	2.9 <sup>d</sup>	4.68 <sup>c</sup>	35.0 <sup>e</sup>
T <sub>5</sub> : 125% RDF of NPK pulse + MOP + Urea	11.40 <sup>a</sup>	45.78 <sup>a</sup>	2.24 <sup>a</sup>	3.46 <sup>a</sup>	5.67 <sup>a</sup>	38.8 <sup>a</sup>
T <sub>6</sub> : Absolute control	8.64 <sup>e</sup>	37.44 <sup>e</sup>	1.70 <sup>d</sup>	2.34 <sup>e</sup>	4.02 <sup>d</sup>	33.5 <sup>f</sup>
CD (P=0.05)	0.132	0.44	0.03	0.06	0.09	1.67

Different lowercase letter indicates significant differences ( $P=0.05$ ) among the treatments as per DMRT.

nitrogen fixation, and fosters root-soil microbial interactions—cumulatively improving yield parameters like pod size, seed count per pod, and test weight. These findings align closely with Fazil *et al.* (2024) who similarly investigated the effects of nitrogen and phosphorus application on growth and yield of mungbean and reported significant improvements in key physiological parameters—such as leaf area duration, net assimilation rate, crop growth rate, pods per plant, seeds per pod, and 1000seed weight—under balanced NPK fertilization regimes, which translated into higher seed and biological yields. Similarly of Singh *et al.* (2010) and Tiwari *et al.* (2011), who similarly observed improvements in pulse crop performance under balanced nutrient application regimes. Additionally, Ghule *et al.* (2020) reported analogous trends in summer green gram (*Vigna radiata* L.), where the application of 125% RDF led to the highest grain yield (15.14 q ha<sup>-1</sup>) and stover yield (32.99 q ha<sup>-1</sup>), followed closely by 100% RDF treatments. Their study also highlighted the significant impact of potassium levels on productivity, with K<sub>3</sub> (25 kg K<sub>2</sub>O ha<sup>-1</sup>) yielding 15.19 q ha<sup>-1</sup> of grain and 33.32

q ha<sup>-1</sup> of stover—statistically comparable to K<sub>2</sub> (20 kg K<sub>2</sub>O ha<sup>-1</sup>), which produced 14.67 q ha<sup>-1</sup> of grain and 32.25 q ha<sup>-1</sup> of stover.

The consistent enhancement in yield parameters across treatments and corroborating studies underscores the efficacy of *balanced and elevated fertilizer regimes* in optimizing crop performance. The present experiment substantiates that T3 and T5 treatments facilitated robust physiological growth and yield expression, thereby reinforcing the importance of precise nutrient management strategies in pulse cultivation.

### Economic Analysis

Economic outcomes across treatments revealed significant variation in cost efficiency, profitability, and return metrics (Table 6).

- ♦ **Cost of Cultivation (₹ ha<sup>-1</sup>):** The highest cultivation costs were incurred under T5 (₹ 71,470.46) and T3 (₹ 70,028.46), reflecting increased input usage at elevated RDF levels. The lowest cost was recorded in the absolute control (T6), amounting to ₹ 61,906.46. Earlier

**Table 2:** Fixed cost of cultivation for Mung bean

Sl. No.	Operation	Input	Rate (₹ ha <sup>-1</sup> )	Cost (₹ ha <sup>-1</sup> )
1	Field operations			
	(a) Ploughing	One tractor (35 HP) for 3hrs.	1000 hr <sup>-1</sup>	3000
	(b) Disc harrowing	One tractor (35 HP) for 3hrs	1000 hr <sup>-1</sup>	3000
	(c) Planking	One tractor (35 HP) for 2hr.	1000hr <sup>-1</sup>	2000
2	Layout	10 farm workers	350 farm worker <sup>-1</sup>	3500
	Seed and sowing			
3	Seed	20kg	250kg <sup>-1</sup>	5000
	Sowing	20 farm workers	350 farm worker <sup>-1</sup>	7000
4	Fertilizer application (Basal application)	10 farm workers	350farm worker <sup>-1</sup>	3500
5	2 Hand Weeding	30 farm workers	350farm worker <sup>-1</sup>	10500
	Insecticide			
6	Profigan plus 44 EC	1500 ml	800 litre <sup>-1</sup>	1200
	Insecticide application	3 farm workers	350 farm worker <sup>-1</sup>	1050
7	Harvesting (Bundle making)	20 farm workers	350 farm worker <sup>-1</sup>	7000
8	Threshing	25 farm workers	350 farm worker <sup>-1</sup>	8750
9	Winnowing	12 farm workers	350 farm worker <sup>-1</sup>	4200
10	Land revenue	For 3 months	250 annum <sup>-1</sup>	63
11	Rental value of land	For 3 months	3000 annum <sup>-1</sup>	750
<b>Total cost</b>				<b>59,813</b>
12	Interest on working capital	For 3 months	14% annually	2,093.46
<b>Grand total</b>				<b>61,906.46</b>

**Table 3:** Variable cost of cultivation for Mung bean crop following graded NPK fertiliser application

Sl. No.	Treatment	Time of application	NPK through fertiliser	Quantity (kg)	Price per Kg (₹)	Cost of fertiliser (₹)	Total cost per treatment
1	T1: 100% RDF through DAP, MOP, Urea	Basal	DAP	108.70	27	2935	4431
			MOP	41.57	34	1413	
			Urea	11.81	7	83	
2	T2: 100% RDF through Groshakti (14:35:14), urea, MOP	Basal	Groshakti (14:35:14)	171.43	15.50	2657	3579
			MOP	26.67	34	907	
			Urea	2.17	7	15	
3	T3: 100% RDF through NPK pulse (14:35:14), MOP, Urea	Basal	NPK pulse (14:34:14)	171.43	42	7200	8122
			MOP	26.67	34	907	
			Urea	2.17	7	15	
4	T4: 75% RDF through NPK pulse (14:35:14), MOP, Urea	Basal	NPK pulse (14:34:14)	128.57	42	5400	6754
			MOP	36.67	34	1247	
			Urea	15.22	7	107	
5	T5: 125% RDF through NPK pulse (14:35:14), MOP, Urea	Basal	NPK pulse (14:34:14)	214.29	42	9000	9564
			MOP	16.6	34	564	
			Urea	0.00	7	0	
6	T6: Absolute control	Basal	No fertiliser	—	—	—	—

RDF = 25-60-40 Kg N-P2O5-K2O per ha, DAP @50Kg = ₹ 1350, MOP @50Kg = ₹ 1700, Urea @50 kg = ₹ 350, Groshakti (14:35:14) @50kg = ₹ 1275, NPK Pulse (14:35:14) @50kg = ₹ 2100.

**Table 4:** Total cost of cultivation for Mung bean crop following graded NPK fertiliser application

Sl. No.	Treatment	Fixed cost (₹ ha <sup>-1</sup> )	Variable cost (₹ ha <sup>-1</sup> )	Total cost of cultivation treatment <sup>1</sup> (₹ ha <sup>-1</sup> )
1	T <sub>1</sub> : 100% RDF (DAP + MOP + Urea)	61,906.46	4431	66,337.46
2	T <sub>2</sub> : 100% RDF of Groshakti + MOP + Urea	61,906.46	3579	65,485.46
3	T <sub>3</sub> : 100% RDF of NPK pulse + MOP + Urea	61,906.46	8122	70,028.46
4	T <sub>4</sub> : 75% RDF of NPK pulse + MOP + Urea	61,906.46	6754	68,660.46
5	T <sub>5</sub> : 125% RDF of NPK pulse + MOP + Urea	61,906.46	9564	71,470.46
6	T <sub>6</sub> : Absolute control	61,906.46	0	61,906.46

**Table 5:** Gross income for Mung bean crop following graded NPK fertiliser application

Sl. No.	Treatments	Seed yield (tha <sup>-1</sup> )	Income from seed (₹/Kg)	Stover yield (tha <sup>-1</sup> )	Income from stover (₹/Kg)	Gross income (₹ ha <sup>-1</sup> )
1	T <sub>1</sub> : 100% RDF (DAP + MOP + Urea)	2.05	205000	3.16	4740	209740
2	T <sub>2</sub> : 100% RDF of Groshakti + MOP + Urea	2.04	204000	3.08	4620	208620
3	T <sub>3</sub> : 100% RDF of NPK pulse + MOP + Urea	2.24	224000	3.40	5100	229100
4	T <sub>4</sub> : 75% RDF of NPK pulse + MOP + Urea	1.91	191000	2.9	4350	195350
5	T <sub>5</sub> : 125% RDF of NPK pulse + MOP + Urea	2.24	224000	3.46	5190	229190
6	T <sub>6</sub> : Absolute control	1.70	170000	2.34	3510	173510

**Table 6:** Economic analysis of for Mung bean crop following graded NPK fertiliser application

Sl. No.	Treatment	Cost of cultivation (₹ ha <sup>-1</sup> )	Gross return (₹ ha <sup>-1</sup> )	Net return (₹ ha <sup>-1</sup> )	B:C	ROI
1	T <sub>1</sub> : 100% RDF (DAP + MOP + Urea)	66,337.46	209740	1,43,402.54	3.16	2.16
2	T <sub>2</sub> : 100% RDF of Groshakti + MOP + Urea	65,485.46	208620	1,43,134.54	3.19	2.19
3	T <sub>3</sub> : 100% RDF of NPK pulse + MOP Urea	70,028.46	229100	1,59,071.54	3.27	2.27
4	T <sub>4</sub> : 75% RDF of NPK pulse + MOP + Urea	68,660.46	195350	1,26,689.54	2.84	1.84
5	T <sub>5</sub> : 125% RDF of NPK pulse + MOP + Urea	71,470.46	229190	1,57,719.54	3.21	2.21
6	T <sub>6</sub> : Absolute control	61,906.46	173510	1,11,603.54	2.80	1.80

findings by Ali *et al.* (2002) and Suman *et al.* (2007) support that NPK application increases production value and cost inputs.

- ♦ **Gross Return (₹ ha<sup>-1</sup>):** T5 yielded the highest gross income (₹ 2,29,190), closely followed by T3 (₹ 2,29,100). The minimum return was observed in T6 (₹ 1,73,510).
- ♦ **Net Return (₹ ha<sup>-1</sup>):** The highest net income was achieved in T3 (₹ 1,59,071.54), slightly surpassing T5 (₹ 1,57,719.54), due to its lower cost of cultivation while maintaining comparable productivity.
- ♦ **Benefit-Cost Ratio (B:C):** T3 recorded the highest B:C ratio (3.27), followed by T5 (3.21), with the lowest observed in T6 (2.80).
- ♦ **Return on Investment (ROI):** ROI trends mirrored B:C patterns—T3 showed a peak ROI of 2.27, followed by T5 (2.21), while T6 lagged at 1.80.

The superior economic performance of T3 and T5 is attributed to balanced nutrient supply, including micronutrients such as 0.5% Zn, 0.2% B, and 0.01% Mo. These elements enhanced root growth and nodulation, improved nitrogen availability via rhizobial association, and supported optimal vegetative and reproductive development—culminating in higher yield and profitability.

The present study demonstrated a clear synergies between balanced nutrient management and enhanced crop performance in terms of yield, physiology, and economics. Treatments T3 (100% RDF of NPK pulse fertilizer + urea + MOP) and T5 (125% RDF of NPK pulse fertilizer + urea + MOP) consistently outperformed other treatments across agronomic and economic parameters.

Yield attributes such as number of seeds per pod, test weight, and biological yield were markedly higher

in T3 and T5. These enhancements were supported by improved vegetative growth, photosynthetic activity, and nutrient assimilation, facilitated by micronutrients (Zn, B, Mo) embedded in the NPK pulse formulation. The increased nodulation and nitrogen fixation observed further amplified plant vigor, flowering, and reproductive success. Similar findings were reported by Kumawat *et al.* (2025), who observed that the combined application of zinc, molybdenum, and NPK consortia significantly improved nodulation, yield attributes, and biological productivity in chickpea. Their results confirmed that micronutrient enrichment not only enhanced nitrogen fixation but also contributed to better seed weight, pod number, and overall plant vigour.

Economically, although T5 incurred the highest cost of cultivation, the net return and gross income remained comparable to T3 due to similar productivity levels. However, T3 emerged as the most cost-effective treatment, showing the highest benefit-cost ratio (3.27) and return on investment (2.27), indicating its superiority in balancing input efficiency with output gains.

These findings resonate with prior studies (Singh *et al.* 2010; Tiwari *et al.* 2011; Ghule *et al.* 2020), reaffirming the efficacy of precise and enriched nutrient management strategies for maximizing pulse crop performance under field conditions.

## CONCLUSION

The application of 100% RDF of NPK pulse fertilizer (14:35:14 enriched with 0.5% Zn, 0.2% B, and 0.01% Mo) + MOP + Urea (T3) provided the most effective balance between productivity and cost-efficiency. The superior performance of this treatment was driven by enhanced root growth, rhizobial association, and micronutrient availability, which collectively improved nutrient uptake,

photosynthetic efficiency, and yield expression. While T3 and T5 (125% RDF of NPK pulse fertilizer + MOP + Urea) were statistically comparable in terms of biological yield and yield-contributing traits, T3 proved economically superior due to lower cultivation costs, thereby offering a more sustainable option for farmers. These findings highlight the importance of integrated nutrient management strategies that combine macronutrients with targeted micronutrient supplementation. Such approaches not only optimize crop performance but also strengthen soil fertility, enhance nitrogen fixation, and improve resource-use efficiency. In the broader context of sustainable agricultural intensification, the adoption of balanced fertilizer formulations like NPK pulse fertilizer can significantly boost pulse productivity, reduce yield gaps, and contribute to nutritional security. This reinforces the relevance of precision nutrient management in advancing both economic viability and ecological sustainability of pulse-based farming systems.

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