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OPTIMIZING MUNGBEAN (*VIGNA RADIATA* L.) PRODUCTIVITY AND ECONOMIC RETURNS THROUGH INTEGRATED NUTRIENT MANAGEMENT IN A SEMI-ARID ENVIRONMENT

Mukesh Vishnoi^{1*}, Vijay Laxmi² and B.K. Pandey³

¹Department of Agronomy Dr. K. N. Modi University Newai Tonk, Rajasthan, 304021, India

²Department of M.D.S.U., Ajmer, Rajasthan, 305009, India

³Department of Agronomy Dr. K.N. Modi University, Newai Tonk, Rajasthan, 304021, India

*Corresponding author E-mail: mukesh29lomror@gmail.com

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ABSTRACT

In semi-arid agricultural systems, mungbean cultivation is frequently hampered by low yields and constrained economic returns. An integrated nutrient management (INM) framework, which harmonizes organic and inorganic nutrient inputs, was investigated as a strategy to address these limitations. This study assessed the effects of various INM protocols on the yield performance, seed quality and financial viability of mungbean (var. K-851) in Rajasthan, India, during the 2024 summer season. A randomized block design was employed to test eight treatments, including an unfertilized control and combinations of recommended fertilizer doses (RDF) with farmyard manure (FYM) or vermicompost, supplemented with *Rhizobium* inoculation. The protocol combining 100% RDF with vermicompost at 1 t/ha and *Rhizobium* (T₈) yielded the most favorable agronomic outcomes, producing the highest seed yield (1040 kg/ha), straw yield (1809 kg/ha) and biological yield (2849 kg/ha). This treatment also achieved superior seed protein content (23.38%) and protein yield (242.9 kg/ha). In economic terms, T₈ also delivered the highest gross (Rs. 79,809/ha) and net returns (Rs. 55,329/ha). Notably, the treatment with 100% RDF, FYM at 2 t/ha and *Rhizobium* (T₃) demonstrated the greatest economic efficiency, with a benefit-cost ratio of 2.68. These results suggest that while vermicompost integration maximizes productivity, the use of FYM with full RDF offers a more cost-effective pathway to enhance mungbean farming in semi-arid regions.

Key words: *Vigna radiata*, INM, vermicompost, farmyard manure, yield components, semi-arid agriculture

Introduction

Mungbean (*Vigna radiata* L.) stands as a crucial pulse crop in India, prized for its nutritional value and adaptability to short growing seasons. However, its potential is often unrealized in semi-arid zones like Rajasthan, where farm-level productivity is frequently constrained by poor soil fertility and non-optimal nutrient management (Singh & Sekhon, 2008). The conventional reliance on chemical fertilizers, while effective for short-term yield gains, raises concerns about long-term soil degradation and environmental health (Virmani, 1994). Moreover, the rising expense of synthetic inputs presents a significant economic barrier for many farmers. A

sustainable intensification strategy is offered by integrated nutrient management (INM), which strategically combines chemical fertilizers with organic amendments and bio-inoculants. Organic inputs such as farmyard manure (FYM) and vermicompost are known to enhance soil physical properties and support a gradual release of nutrients through microbial decomposition (Raghuwanshi *et al.*, 2016). Concurrently, biofertilizers like *Rhizobium* can augment biological nitrogen fixation, thereby lessening the crop's dependence on external nitrogen sources (Pattanayak *et al.*, 2007). The synergy between these components can foster a more balanced and sustained nutrient supply, promoting better crop performance (Verma

Table 1: Mungbean Yield Attributes as Influenced by Different Nutrient Management Treatments.

Treatment	Number of Pods per Plant	Number of Seeds per Pod	Test Weight (g)
T ₁ : Control	13.67	7.73	25.73
T ₂ : 100% RDF + Rhizobium	16.40	9.00	28.46
T ₃ : 50% RDF + FYM @ 2 t/ha + Rhizobium	16.73	9.33	28.79
T ₄ : 75% RDF + FYM @ 2 t/ha + Rhizobium	19.47	10.87	31.53
T ₅ : 100% RDF + FYM @ 2 t/ha + Rhizobium	19.93	11.33	31.99
T ₆ : 50% RDF + Vermicompost @ 1 t/ha + Rhizobium	17.40	9.40	29.46
T ₇ : 75% RDF + Vermicompost @ 1 t/ha + Rhizobium	19.73	11.13	31.79
T ₈ : 100% RDF + Vermicompost @ 1 t/ha + Rhizobium	20.33	11.33	32.39
S.Em. ±	0.855	0.344	0.820
CD (P=0.05)	2.59	1.04	2.49

et al., 2012). A clear understanding of the most effective INM combinations for mungbean within the specific agro-ecological context of semi-arid Rajasthan is essential. This research was designed to address that gap, with a focused evaluation of how different INM treatments influence:

- (1) yield and its core components,
- (2) key seed quality markers and
- (3) the overall economic feasibility of the production system.

Materials and Methods

Experimental Design and Treatments

This field investigation was executed in Newai, Rajasthan, India, during the 2024 summer (*zaid*) season. The experimental site featured loamy sand soil with low native nitrogen, medium phosphorus and high potassium content. A randomized block design with three replications formed the statistical layout. The study encompassed eight distinct nutrient management protocols: T₁ (Control), T₂ (100% RDF + *Rhizobium*), T₃ (50% RDF + FYM @ 2 t/ha + *Rhizobium*), T₄ (75% RDF + FYM @ 2 t/ha + *Rhizobium*), T₅ (100% RDF + FYM @ 2 t/ha + *Rhizobium*), T₆ (50% RDF + Vermicompost @ 1 t/ha + *Rhizobium*), T₇ (75% RDF + Vermicompost @ 1 t/ha +

Rhizobium) and T₈ (100% RDF + Vermicompost @ 1 t/ha + *Rhizobium*). The standard RDF was defined as 20 kg N, 60 kg P₂O₅ and 20 kg K₂O per hectare. The mungbean cultivar 'K-851' was cultivated in individual plots of 18.0 m² (5.0 m × 3.6 m).

Data Collection and Analysis

At the time of harvest, yield-contributing traits such as the number of pods per plant and seeds per pod were quantified from five randomly selected plants in each plot. The 1000-seed test weight was measured from a representative seed sample. The total seed and stover yields from each net plot were weighed and the data were extrapolated to a per-hectare basis (kg/ha). The sum of seed and stover yields constituted the biological yield. To assess seed quality, nitrogen concentration in the seeds was determined via the micro-Kjeldahl method. This nitrogen value was then used to compute the seed protein content, using a conversion factor of 6.25. The total protein yield (kg/ha) was subsequently calculated by integrating the seed yield with the protein percentage. An economic assessment was conducted using the prevailing market prices for agricultural inputs and harvested produce. The gross return was computed based on the combined market value of the seed and stover. The net return was ascertained by deducting the total

Table 2: Effect of Integrated Nutrient Management on Mungbean Yields.

Treatment	Seed yield (kg/ha)	Stover yield (kg/ha)	Biological yield (kg/ha)
T ₁ : Control	625	1217	1842
T ₂ : 100% RDF + Rhizobium	880	1618	2498
T ₃ : 50% RDF + FYM @ 2 t/ha + Rhizobium	820	1457	2277
T ₄ : 75% RDF + FYM @ 2 t/ha + Rhizobium	896	1625	2521
T ₅ : 100% RDF + FYM @ 2 t/ha + Rhizobium	985	1725	2710
T ₆ : 50% RDF + Vermicompost @ 1 t/ha + Rhizobium	855	1556	2411
T ₇ : 75% RDF + Vermicompost @ 1 t/ha + Rhizobium	930	1646	2575
T ₈ : 100% RDF + Vermicompost @ 1 t/ha + Rhizobium	1040	1809	2849
S.Em. ±	60.25	107.53	164.46
CD (P=0.05)	182.76	326.17	498.83

cultivation costs from the gross return. To gauge investment efficiency, the benefit-cost (B:C) ratio was derived by dividing the net return by the cultivation cost. All empirical data underwent an analysis of variance (ANOVA), with the Critical Difference (CD) test applied at a 5% probability level to discern significant variations among treatment means, following the methodology of Panse & Sukhatme (1985).

Results and Discussion

Integrated nutrient management significantly influenced yield attributes, yield, seed quality and economic returns of mungbean under semi-arid conditions. Across all parameters, treatments combining inorganic fertilizers with organic manures and Rhizobium inoculation consistently outperformed the unfertilized control, confirming the advantages of balanced and integrated nutrient supply.

Influence on Yield Attributes

The application of integrated nutrient management treatments markedly improved yield-contributing characters such as number of pods per plant, seeds per pod and test weight (Table 1; Fig. 1). The maximum number of pods per plant (20.33) was recorded under T8 (100% RDF + vermicompost @ 1 t ha⁻¹ + Rhizobium), which remained statistically at par with T₅, T₇ and T₄. Similarly, the highest number of seeds per pod (11.33) was observed in T8 and T5, while the control recorded the lowest values. Test weight followed a comparable trend, with T₈ registering the maximum value (32.39 g), significantly higher than the unfertilized control.

The superior performance of integrated treatments can be attributed to the synergistic effects of inorganic fertilizers and organic amendments. Chemical fertilizers ensured immediate nutrient availability, whereas organic

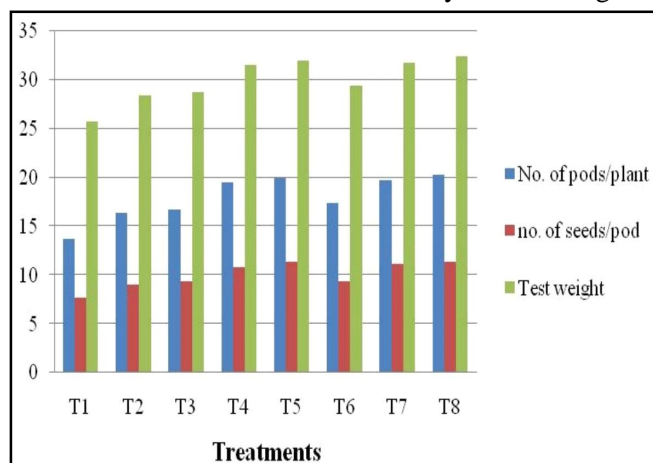


Fig. 1: Comparative effect of INM treatments on key yield attributes: pods per plant, seeds per pod and test weight.

sources provided a sustained nutrient release through gradual mineralization. This balanced nutrient supply promoted vigorous vegetative growth, improved photosynthetic efficiency and enhanced assimilate translocation towards reproductive sinks, leading to improved yield attributes. The beneficial role of vermicompost in improving nutrient availability and microbial activity has also been reported earlier in mungbean (Tyagi *et al.*, 2014; Vadgave, 2010).

Impact on Seed, Stover and Biological Yields

Seed, stover and biological yields were significantly influenced by different nutrient management practices (Table 2; Fig. 2). The highest seed yield (1040 kg ha⁻¹) was obtained under T₈, representing a 66.4% increase over the control. This treatment also recorded the maximum stover yield (1809 kg ha⁻¹) and biological yield (2849 kg ha⁻¹). Treatments T₅, T₇ and T₄ remained statistically at par with T₈ for seed yield, indicating that higher productivity can be achieved when recommended fertilizer doses are integrated with organic sources.

The enhanced yields under integrated nutrient management can be explained by improved soil physical properties, better root growth and increased nutrient uptake efficiency. Vermicompost, in particular, supplies macro- and micronutrients in readily available forms and enhances microbial-mediated nutrient transformations, which improves crop nutrient synchronization under semi-arid conditions. Similar improvements in mungbean productivity due to integrated application of RDF and vermicompost have been documented by Tyagi *et al.*, (2014) and Vadgave (2010).

Effects on Quality Parameters

Integrated nutrient management significantly

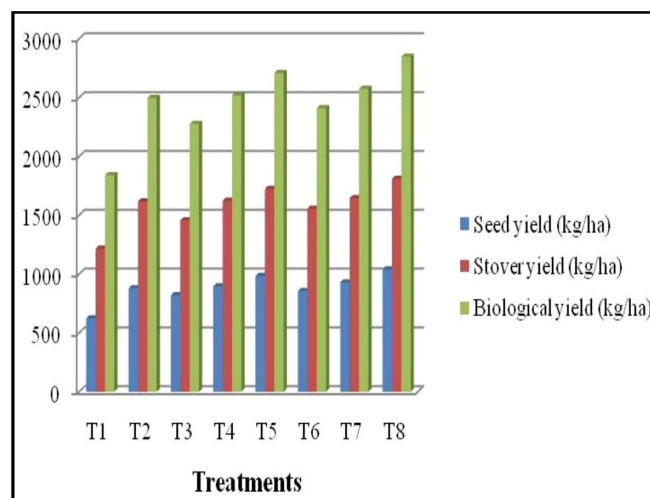


Fig. 2: Influence of Integrated Nutrient Management Strategies on Mungbean Seed, Stover and Biological Yields (kg/ha).

Table 3: Seed Protein Content and Protein Yield of Mungbean under Different INM Treatments.

Treatment	Protein Content (%)	Protein Yield (kg/ha)
T ₁ : Control	21.25	132.93
T ₂ : 100% RDF + Rhizobium	22.08	193.91
T ₃ : 50% RDF + FYM @ 2 t/ha + Rhizobium	22.25	182.74
T ₄ : 75% RDF + FYM @ 2 t/ha + Rhizobium	22.94	205.64
T ₅ : 100% RDF + FYM @ 2 t/ha + Rhizobium	23.17	228.27
T ₆ : 50% RDF + Vermicompost @ 1 t/ha + Rhizobium	22.42	191.74
T ₇ : 75% RDF + Vermicompost @ 1 t/ha + Rhizobium	23.02	213.83
T ₈ : 100% RDF + Vermicompost @ 1 t/ha + Rhizobium	23.38	242.90
S.Em.±	0.199	13.497
CD (P=0.05)	0.60	40.94

Table 4: Economic Viability of Mungbean Cultivation under Different INM Treatments.

Treatment	Gross Return (Rs./ha)	Net Return (Rs./ha)	Benefit:Cost Ratio
T ₁ : Control	48,092	30,892	1.80
T ₂ : 100% RDF + Rhizobium	67,596	48,096	2.47
T ₃ : 50% RDF + FYM @ 2 t/ha + Rhizobium	62,957	43,307	2.20
T ₄ : 75% RDF + FYM @ 2 t/ha + Rhizobium	68,840	48,590	2.40
T ₅ : 100% RDF + FYM @ 2 t/ha + Rhizobium	75,600	55,050	2.68
T ₆ : 50% RDF + Vermicompost @ 1 t/ha + Rhizobium	65,681	43,421	1.95
T ₇ : 75% RDF + Vermicompost @ 1 t/ha + Rhizobium	71,373	48,003	2.05
T ₈ : 100% RDF + Vermicompost @ 1 t/ha + Rhizobium	79,809	55,329	2.26

improved seed protein content and protein yield of mungbean (Table 3). The highest protein content (23.38%) and protein yield (242.9 kg ha⁻¹) were recorded under T₈, followed closely by T₅ and T₇. In contrast, the control treatment produced seeds with the lowest protein concentration and protein yield.

The increase in protein content under integrated treatments is primarily associated with improved nitrogen availability throughout the crop growth period. Nitrogen supplied through inorganic fertilizers, biological nitrogen fixation by Rhizobium and mineralization of organic manures collectively ensured sustained nitrogen availability during seed development. Since nitrogen is a fundamental component of amino acids and proteins, enhanced nitrogen nutrition directly translated into higher seed protein accumulation. Similar responses of protein content and protein yield to integrated nutrient management in mungbean have been reported by Malik *et al.*, (2014) and Kinkar (2007).

Economics

Economic evaluation revealed substantial variation in profitability among the treatments (Table 4). The highest gross return (Rs. 79,809 ha⁻¹) and net return (Rs. 55,329 ha⁻¹) were obtained under T₈, owing to its superior seed and stover yields. However, the highest benefit-cost ratio (2.68) was recorded under T₅ (100% RDF +

FYM @ 2 t ha⁻¹ + Rhizobium), indicating greater economic efficiency compared to vermicompost-based treatments.

Although vermicompost-based treatment T₈ maximized yield and net returns, its higher input cost reduced the benefit-cost ratio. In contrast, FYM-based treatment T₅ offered a more economical nutrient source while maintaining high productivity, resulting in better returns per unit investment. Similar findings emphasizing the economic advantage of integrating RDF with FYM or other organic manures in legume-based systems have been reported by Kishor *et al.*, (2021) and Singh *et al.*, (2017).

Conclusion

The results from this single-season field study lead to the conclusion that integrated nutrient management is a potent strategy for enhancing the productivity, quality and profitability of mungbean in the semi-arid conditions of Rajasthan. For producers aiming to maximize absolute yield and net income, the combined application of 100% RDF (20:60:20 kg NPK/ha), vermicompost at 1 t/ha and *Rhizobium* seed inoculation is the recommended course of action. Conversely, for those prioritizing economic efficiency and the highest return on investment, a protocol combining 100% RDF with farmyard manure at 2 t/ha and *Rhizobium* inoculation proves to be the most judicious choice. These findings provide farmers with distinct, viable pathways to sustainably intensify mungbean production.

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