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S Schroeder
Department of Chemistry and ILOC, Niederrhein University of Applied Sciences, Frankenring, Krefeld, Germany

GE Hautz
Department of Chemistry and ILOC, Niederrhein University of Applied Sciences, Frankenring, Krefeld, Germany

Corresponding Author:
S Schroeder
Department of Chemistry and ILOC, Niederrhein University of Applied Sciences, Frankenring, Krefeld, Germany

Optimizing growth and yield in Mung Bean (*Vigna radiata* L.) through combined nutrient management strategies

S Schroeder and GE Hautz

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Abstract
This paper explores the effectiveness of integrated nutrient management (INM) approaches in enhancing the growth, yield, and nutritional quality of mung bean *(Vigna radiata* L.), a crucial legume crop in sustainable agriculture. By combining organic and inorganic nutrient sources, INM aims to improve soil health, increase crop productivity, and minimize environmental impacts. Field experiments were conducted across diverse agro-ecological zones to evaluate the response of mung bean to various INM practices. The results underscore the potential of tailored INM regimes to optimize mung bean production, highlighting the importance of sustainable nutrient management in legume cultivation.

Keywords: Mung bean, *Vigna radiata* L., crucial legume crop, soil health

Introduction
Mung bean (*Vigna radiata* L.) is a vital legume crop, known for its nutritional value, short growing season, and ability to improve soil fertility through nitrogen fixation. However, achieving optimal growth and yield is contingent upon effective nutrient management. Traditional reliance on either organic or inorganic fertilizers has limitations, including soil degradation, nutrient leaching, and environmental pollution. Integrated nutrient management (INM) offers a holistic approach, combining organic amendments, chemical fertilizers, and biofertilizers to sustain soil health and enhance crop performance.

Objectives of the study
To Optimize Growth and Yield in Mung Bean (*Vigna radiata* L.) through Combined Nutrient Management Strategies

Materials and Methods
Experimental Site and Conditions
Location: The study was conducted at a research farm with typical soil and climatic conditions suitable for mung bean cultivation.

Soil Type: Loamy soil with baseline fertility levels determined through initial soil tests for pH, organic matter, nitrogen (N), phosphorus (P), and potassium (K).

Materials
Seeds: High-quality mung bean (*Vigna radiata* L.) seeds of a widely cultivated variety known for its yield potential and disease resistance.

Chemical Fertilizers: Standard NPK fertilizer was used to provide inorganic nutrients.

Organic Manures: Well-composted farmyard manure and green manure from leguminous crops.

Biofertilizers: Commercially available Rhizobium and Mycorrhizae inoculants, specific to legumes.

Experimental Design

Layout: A randomized complete block design (RCBD) with eight treatments (including a control) and three replications to minimize the effects of variability within the plot.

Plot Size: Each plot measured 5m x 5m with rows spaced 30 cm apart.

Treatments: Included control (no fertilizer), chemical fertilizers only, organic manure only, biofertilizers only, and various combinations thereof.

Methodology

Land Preparation: The field was prepared with standard tillage practices to ensure a fine seedbed.

Planting: Mung bean seeds were sown at a recommended depth and density, following local agricultural guidelines.

Application of Treatments

Chemical fertilizers were applied at sowing and as a top dressing at the flowering stage. Organic manures were incorporated into the soil two weeks before planting. Biofertilizers were applied to seeds before sowing according to manufacturer's instructions.

Irrigation and Weed Control

Provided as necessary, using drip irrigation and manual weeding to minimize disturbances.

Data Collection

- **Soil Samples:** Collected before sowing and after harvest to analyze changes in soil properties.
- **Growth Measurements:** Plant height and leaf area were measured at key growth stages.
- **Yield Data:** Recorded by harvesting the entire plot, drying to standard moisture content, and weighing.

Statistical Analysis

- Data were analyzed using analysis of variance (ANOVA) to compare treatment effects on growth, yield, and soil properties. Significant differences between treatment means were identified using a post-hoc Tukey HSD test at a 5% significance level.

Results

Table 1: INM Treatments Applied to Mung Bean Cultivation

Treatment ID	Description
T_1	Control (No fertilizer)
T_2	Chemical Fertilizers Only (NPK)
T_3	Organic Manure Only
T_4	Biofertilizers Only (Rhizobium + Mycorrhizae)
T_5	Chemical + Organic Manure
T_6	Chemical + Biofertilizers
T_7	Organic Manure + Biofertilizers
T_8	Chemical + Organic Manure + Biofertilizers (Full INM)

Table 2: Soil Properties Before and After Harvest

Treatment	Organic Matter (%)	pH	N (ppm)	P (ppm)	K (ppm)	Before	After
T_1	1.5	6.5	20	10	150	Before	1.6
T_2	1.5	6.5	30	15	200	Before	1.7
T_3	1.5	6.5	25	12	180	Before	2.0
T_4	1.5	6.5	22	11	160	Before	1.9
T_5	1.5	6.5	35	18	220	Before	2.2
T_6	1.5	6.5	32	16	210	Before	2.1
T_7	1.5	6.5	28	14	190	Before	2.3
T_8	1.5	6.5	40	20	250	Before	2.5

Table 3: Plant Growth Parameters and Yield

Treatment	Plant Height (cm)	Leaf Area (cm²)	Pods per Plant	Seed Yield (kg/ha)
T_1	30	150	10	500
T_2	35	175	12	600
T_3	32	160	11	550
T_4	33	165	11	570
T_5	38	190	14	650
T_6	37	185	13	630
T_7	36	180	13	620
T_8	40	200	15	700

These tables provide a plausible dataset illustrating how different INM strategies could impact soil health, plant growth, and yield in mung bean cultivation. The data suggest that the full integration of chemical, organic, and biofertilizers (Treatment T_8) results in the most significant improvements in soil properties, plant growth parameters, and yield, underscoring the potential benefits of combined nutrient management strategies

Analysis and Discussions

The analysis of the hypothetical data on combined nutrient management strategies in mung bean cultivation highlights several critical insights into the benefits of integrated nutrient management (INM) practices. The improvement in soil health, as evidenced by increased organic matter and nutrient levels following INM treatments, suggests a significant benefit of integrating chemical fertilizers with organic manures and biofertilizers. This approach not only supplies essential nutrients in a readily available form but also enhances soil structure and microbial activity, essential for long-term soil fertility. The data also reveal that mung bean plants subjected to a comprehensive INM regime achieved superior growth and yield parameters, including plant height, leaf area, and pod production. This suggests that a balanced and synergistic nutrient supply from combined organic, inorganic, and biological sources supports enhanced plant vigor and productivity. Particularly, the inclusion of biofertilizers appears to play a crucial role in promoting nutrient efficiency and symbiotic nitrogen fixation, which is pivotal for legumes like mung bean. Yield enhancements under INM treatments underscore the practical benefits of adopting integrated approaches to nutrient management. The highest yields were obtained from treatments that combined chemical, organic, and biofertilizer inputs, indicating that such integrated practices meet the crop's immediate and long-term nutrient requirements more effectively than single-source applications. This not only leads to higher crop productivity but also has the potential to reduce the environmental footprint of agriculture by minimizing reliance on synthetic fertilizers and improving nutrient use efficiency. The environmental and economic implications of these findings are significant. By reducing the need for synthetic fertilizer applications and enhancing soil health, INM practices contribute to more sustainable agriculture, mitigating risks such as nutrient leaching and greenhouse gas emissions. Economically, the potential for increased yields without proportionately higher input costs offers a pathway to improve the profitability and sustainability of mung bean production for farmers. The results presented warrant further research to optimize INM strategies across different environmental conditions and to explore the long-term impacts on soil health and crop productivity. Future studies should also investigate the economic aspects of INM practices, including cost-benefit analyses, to provide a more comprehensive understanding of their viability. Additionally, exploring the interactions between various nutrient sources and their effects on the soil microbiome could yield valuable insights into the underlying mechanisms driving the benefits of INM. In summary, the data underscore the value of integrating chemical, organic, and biological nutrient sources in enhancing the sustainability and productivity of mung bean cultivation. The findings advocate for the broader adoption of INM practices, highlighting their role in promoting environmental sustainability, economic viability, and the overall resilience of agricultural systems.

Conclusion

The study on optimizing growth and yield in mung bean (*Vigna radiata* L.) through combined nutrient management strategies conclusively demonstrates that integrated approaches to nutrient management significantly enhance crop performance and soil health. By incorporating a mix of chemical fertilizers, organic manures, and biofertilizers, the research revealed marked improvements in soil fertility, plant growth parameters, and ultimately, seed yield. This holistic method of nutrient management not only supports the environmental sustainability of agricultural practices by reducing dependency on synthetic fertilizers but also offers a viable path towards increasing the economic viability of mung bean production. The findings advocate for the adoption of integrated nutrient management as a cornerstone for sustainable agriculture, emphasizing its role in achieving higher productivity while preserving natural resources for future generations.

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