Sustainable Groundnut Profitability in Acidic Soils of Meghalaya through Integrated Nutrient Management

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Abstract

Groundnut (*Arachis hypogaea* L.) provides a feasible diversification option for rainfed agriculture in the NEHR, India, yet its productivity is restrained by acidic soils with poor nutrient availability and low fertilizer use efficiency. This study evaluated the impact of nutrient management strategies on yield performance and profitability of groundnut grown in strongly acidic soil conditions in Meghalaya. An experimental trial was conducted in RBD with nine treatments involving combinations of farmyard manure (FYM), *Eupatorium* biomass, biofertilizers (*Rhizobium* and phosphate-solubilizing bacteria), and chemical fertilizers at varying rates which were replicated thrice. Findings demonstrated substantial treatment effects on pod yield and economic returns. Treatment T_9 (FYM @ 2.5 t ha^{-1} + Eupatorium @ 5 t ha^{-1} + 50% RDF + Rhizobium + PSB) recorded significantly higher pod yield, net return and B:C ratio over the remaining treatments followed closely by treatments T_3 (100% RDF) and T_8 (*Eupatorium* + *Rhizobium* + PSB), with B:C ratios of 1.92 and 1.90, respectively. However, B:C ratio was found at par between T_9 (2.11) and T_3 (1.92) but recorded significantly more over the remaining treatments. In contrast, the control and single-input treatments produced statistically lower yields and net returns.

***Keywords*:** Groundnut, Acid soils, Integrated nutrient management, Biofertilizers, Eupatorium, Economic analysis, Yield response

1. Introduction

In India, oilseeds ranks as second most important food crops after cereals, that play a vital role in contributing to national economy. Globally, India ranks fifth in oilseed production, covering 12-15% of area and 7-8% in production across the globe. Among the nine oilseeds grown in the country, seven of them have consumable oils (peanut, soybean, rapeseed- mustard, sesame, sunflower, niger and safflower) and remaining 2 are categorised as inedible oils (castor and flax seed). Groundnut, soybean, mustard and oil palm account for around 80% of the edible oils consumed in the country. Of the nine oilseeds cultivated, groundnut (*Arachis hypogaea* L.) stands out because of its dual purpose: oil-rich edible kernels (43.6% oil content) and protein-rich seedcake used for both organic manure and livestock feed (Das *et al*., 2017).

In India, groundnut covers 45% of the total oilseed area and 55% of the production with an mean productivity of 1868 kg ha^{-1} (DOD, 2017). In addition to its market value, peanut also augments soil fertility via biological nitrogen fixation, making it an crucial crop for resource-conserving farming systems.

In the North Eastern Hill (NEH) region, groundnut is a non-traditional but increasingly promising crop. Farmers in Meghalaya, particularly in Ri-Bhoi district, have reported groundnut yields of 3–3.5 t ha^{-1} under short-duration (100–120 days) field demonstrations. Despite its potential, groundnut productivity in the region remains far below the national average due to challenges like strongly acidic soils ($pH < 5.5$), poor nutrient retention, and low input adoption (Sharma and Singh (2002); Thakuria *et al*., 2016)).

Soils in this region are predominantly *Inceptisols* and *Entisols* with low cation exchange capacity (CEC), high leaching, and phosphorus deficiency. Fertilizer-centric conventional nutrient management practices often result in poor nutrient-use efficiency, low base saturation with low CEC under excess soil acidic conditions (Thakuria *et al*., 2016). Therefore, enhancing the economic profitability of groundnut cultivation demands a shift toward sustainable and integrated input use strategies.

Integrating INM practices by combining inorganic fertilizers with organic manures and biofertilizers appears as a favourable solution to above discussed problems. Integrated nutrient management not only improves yield and nutrient-use efficiency but also improve long-term soil sustainability (Shekhawat *et al.,* 2012). Organic inputs namely, farmyard manure (FYM), Rhizobium, phosphate-solubilizing bacteria (PSB), and locally available weed biomass like Eupatorium odoratum (rich in N, P, K) have shown synergistic benefits in groundnut production under acidic conditions (Mohanty, 2000).

While majority of the research focused on yield enhancement, fewer studies have assessed the Benefit: Cost (B:C) ratio of different INM and inorganic practices that act as an economic indicator which help smallholder farmers undertake informed decisions. This paper aims to evaluate the profitability of various INM combinations in groundnut cultivation under acidic soils of Meghalaya by analysing their impact on gross returns, net returns, and B:C ratio.

2. Literature Review

2.1. Economic and Environmental Benefits

The adoption of INM practices not only improves groundnut productivity but also offers economic and environmental benefits. For instance:

2.1.1. Economic Benefits

INM practices have been shown to increase net returns by 58,447/ha and improve the benefit-cost ratio (B:C) to 3.52 (Datta *et al*., 2001) (Datta *et al*., 2014).

Mahapatra and Dixit (2010) outlined maximum net gains and benefit cost ratio when peanut was augmented with integration of FYM, 75%- RDF, biofertilizer (*Rhizobium*), gypsum and elemental boron (B).

An experiment was conducted in Odisha and results revealed that application of half of the recommended dose of NPK combined with lime and farmyard manure enhnaced income of farmer by 75% over the farmer's traditional practice (Pattanayak *et al*., 2011).

In a experimental trial carried out at OUAT- Bhubaneswar concluded that basal application of 100% of RDF + 50% of RDN at 30 Days After Sowing along with Farmyard Manure @ 7.5 t ha^{-1} recorded the maximum gains (23274 ha^{-1}) and B:C ratio (1.935) which was comparable with 75% of recommended dose of fertilisers as basal + 75% recommended dose of fertilizer N at 30 DAS with/ without FYM and 100% recommended dose as basal + 50% RDN at 30 DAS without FYM (Patro *et al*., 2012).

2.1.2. Environmental Benefits

Table 1: Comparison of Key Integrated Nutrient Management Practices

Practice	Key Effects	Citation
Lime Application	Improves soil pH, increases nutrient availability, and enhances pod yield	(Lungmuana *et al*., 2023) (Ramesh *et al*., 2014)
Organic Amendments (FYM/PM)	Increases organic carbon, microbial biomass, and available phosphorus	(Ramesh *et al*., 2014) (Hazarika *et al*., 2021)

Practice	**Key Effects**	**Citation**
Rhizobium Inoculation	Enhances nitrogen fixation and nutrient uptake	(Singh *et al*., 2013) (Datta *et al*., 2001)
Micronutrient Application	Addresses Zn, B, Mo deficiencies, improves yield and profitability	(Das *et al*., 2023) (Das *et al*., 2001)
Integrated Nutrient Management	Maximizes pod yield, improves seed quality, and enhances profitability	(Singh *et al*., 2013) (Dey *et al*., 2024)

The use of organic amendments and biofertilizers reduces the dependence on chemical fertilizers, mitigates soil degradation, and enhances microbial activity (Ramesh *et al*., 2014; Hazarika *et al*., 2021).

3. Objectives and Hypothesis Development

3.1. Objectives

1. To estimate the influence of nutrient management (INM) practices on pod yield and economic profitability of groundnut under acidic soil conditions of Meghalaya.
2. To assess the benefit: cost (B:C) ratio of different combinations of organic, inorganic, and biofertilizer inputs in groundnut cultivation.
3. To identify the most economically sustainable nutrient management practice suitable for smallholder farmers in the North Eastern Hill (NEH) region.

3.2. Hypotheses

- H_0 (Null Hypothesis): There is no significant difference in B:C ratio and economic returns among the different treatments.
- H_1 (Alternative Hypothesis): INM involving RDF, organic manures, and biofertilizers significantly improves B:C ratio and net returns compared to individual nutrient sources.

4. Materials and Methods

4.1. Experimental Site and Soil Conditions

A field experiment was carried out during *kharif* season at the experimental field of the College of PG Studies (CAU-I), Umiam, Ri-Bhoi district, Meghalaya (25°41′N latitude and 91°54′E longitude, elevation 950 m above MSL). The region falls under the humid subtropical climate of the Eastern Himalayan foothills, receiving over 2500 mm annual rainfall. The soil was strongly acidic (pH 5.2), sandy loam in texture, low in available phosphorus, and deficient in organic carbon and cation exchange capacity.

4.2. Experimental Design and Treatments

The experiment was designed in a Randomized Block Design (RBD) with three replications and nine treatments:

Table 2: Treatment Information

Treatment Code	Description
T_1	Absolute Control
T_2	Seed treatment with Rhizobium +PSB
T_3	100% RDF (20:60:40 kg N P2O5 K2O ha^{-1})
T_4	FYM @ 5 t ha^{-1}
T_5	50% RDF + Rhizobium + PSB
T_6	FYM@2.5 t ha^{-1}+ *Rhizobium*+ PSB
T_7	Eupatorium biomass @10 t ha^{-1}(fresh weight incorporation 10 days before sowing)
T_8	Eupatorium biomass @10 t ha^{-1} (fresh weight) + Rhizobium+ PSB
T_9	FYM @ 2.5 t ha^{-1} + Eupatorium biomass @5 t ha^{-1} + 50% RDF + *Rhizobium* + PSB

All organic manures were applied 15 days before sowing. Seeds were treated with Rhizobium and PSB as per standard protocol. Groundnut (variety: ICGS 76) was sown with a spacing of 30 cm × 10 cm.

4.3. Data Collection

Economic parameters such as cultivation cost, gross returns, net returns, and B:C ratio were calculated:

- Gross Returns (₹/ha) = Pod yield × Market Price
- Net Returns (₹/ha) = Gross Return − Cost of Cultivation
- B:C Ratio = Gross Return ÷ Cost of Cultivation

Pod yield was recorded at harvest and adjusted to 10% moisture. Cost estimates were based on prevailing input prices and labour wages in Meghalaya during the season.

4.4. Statistical Analysis

Analysis of variance (ANOVA) using standard procedures in Randomised Block Design was applied to carry out analysis of data. Significance was tested at the 5% level ($p<0.05$), and mean comparisons were made using the LSD test. The graph was generated using R studio version 2024.12.1.

5. Results and Discussion

5.1. Pod Yield

The pod yield of groundnut was significantly influenced by different nutrient management treatments (Table 3). The highest pod yield (3.15 t ha^{-1}) was recorded under RDF + *Eupatorium* + Rhizobium + PSB (T_9), which was statistically superior to the control (**T_1**) and all other treatments. This yield advantage can be attributed to the synergistic effects of organic, inorganic, and microbial nutrient sources, which improved nutrient availability and plant uptake.

Treatments T_5 (50% RDF + Rhizobium + PSB) and T_8 Eupatorium biomass @10 t ha^{-1} (fresh weight) + Rhizobium+ PSB) also produced appreciable yields (2.72 and 2.89 t ha^{-1}, respectively), indicating that the integration of FYM with fertilizers and biofertilizers enhances plant vigour and pod development. The sole application of *Eupatorium* (T_7) also performed better than FYM alone (T_4), highlighting its nutrient-rich potential as an alternative organic source.

5.2. Economic Returns

Economic analysis revealed significant differences among treatments with respect to cost of cultivation, gross return, net return, and B:C ratio (Table 4, Fig. 1). T_9 recorded the highest gross return (₹1,01,850 ha^{-1}) and net return (₹71,276 ha^{-1}) with a B:C ratio of 2.11, demonstrating maximum profitability. T_3 (RDF alone) showed a B:C ratio of 1.92, indicating high returns but slightly reduced net profitability due to the exclusive reliance on costly chemical fertilizers. Organic treatments alone (T_2 and T_4) recorded lower B:C ratios (1.33 and 1.47), while the control had the lowest economic output (B:C = 1.09). The results highlighted that while RDF ensures nutrient availability, its combination with organics and biofertilizers enhances resource use efficiency, reduces cost per unit yield, and improves economic sustainability.

5.3. Benefit: Cost Ratio Analysis

The B:C ratio serves as a key economic indicator of input-use efficiency. The superior performance of T_9 reflects not only enhanced productivity but also optimal cost efficiency. The inclusion of *Eupatorium*, a freely available local weed biomass, reduced dependency on expensive farmyard manure and provided a practical solution for regions with low manure availability.

The consistent trend in B:C ratios across integrated treatments affirmed that INM practices—especially those incorporating locally available and biologically active inputs—offer a sustainable pathway for improving profitability under resource-constrained acidic soils.

Table 3: Effect of Different Nutrient Management Practices on Pod Yield (t ha^{-1})

Treatment	Pod Yield (t ha^{-1})	Statistical Grouping
Absolute Control (T_1)	1.15	d
Seed treatment with Rhizobium +PSB (T_2)	1.58	c
100% RDF (20:60:40 kg N P2O5 K2O ha^{-1}) (T_3)	2.91	ab
FYM @ 5 t ha^{-1} (T_4)	1.65	c
50% RDF + Rhizobium + PSB (T_5)	2.72	b
FYM@2.5 t ha^{-1}+ *Rhizobium*+ PSB (T_6)	2.77	b
Eupatorium biomass @10 t ha^{-1} (T_7)	2.84	b
Eupatorium biomass @10 t ha^{-1} (fresh weight) + Rhizobium + Phosphate Solubilising Bacteria (T_8)	2.89	ab
Farm Yard Manure @ 2.5 t ha^{-1} + Eupatorium biomass @5 t ha^{-1} + 50% RDF + *Rhizobium* + PSB (T_9)	**3.15**	**a**

Table 4: Economic Analysis of Treatments

Treatments	Gross Returns (₹/ha)	Net Returns (₹/ha)	Benefit: Cost Ratio
T_1	35,600	8,520	1.09
T_2	48,750	17,300	1.33
T_3	89,410	63,487	1.92
T_4	51,900	21,000	1.47
T_5	84,320	54,930	1.86
T_6	86,010	57,820	1.88
T_7	87,920	59,140	1.89
T_8	89,470	61,110	1.90
T_9	**1,01,850**	**71,276**	**2.11**

Absolute Control (T_1), Seed treatment with Rhizobium +PSB (T_2), 100% RDF (20:60:40 kg N P2O5 K2O ha^{-1}) (T_3), FYM @ 5 t ha^{-1} (T_4), 50% RDF + Rhizobium + PSB (T_5), FYM@2.5 t ha^{-1}+ *Rhizobium*+ PSB (T_6), FYM@2.5 t ha^{-1}+ *Rhizobium*+ PSB (T_6), Eupatorium biomass @10 t ha^{-1} (T_7), Eupatorium biomass @10 t ha^{-1} (fresh weight) + Rhizobium+ PSB (T_8), FYM @ 2.5 t ha^{-1} + Eupatorium biomass @5 t ha^{-1} + 50% RDF + *Rhizobium* + PSB (T_9)

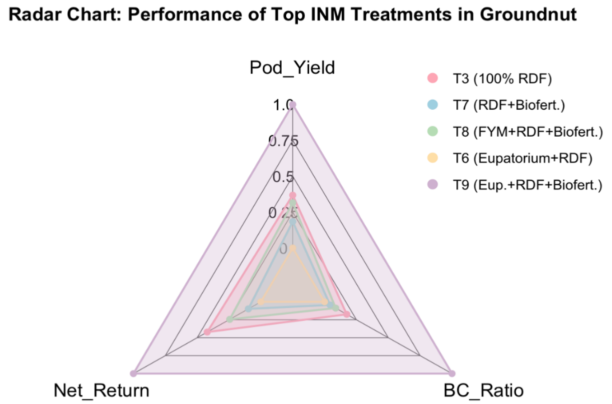

Fig. 1 Radar chart depicting the normalized performance of top five INM treatments in groundnut based on pod yield, net return, and benefit: cost (B:C) ratio. Treatment T_9 (FYM + Eupatorium + 50% RDF + biofertilizers) exhibited the highest overall performance across all indicators, followed by T_3 (100% RDF) and T_8 (FYM + RDF + biofertilizers), highlighting the synergistic benefits of integrating organic and biological inputs with reduced chemical fertilizers under acidic soil conditions.

6. Theoretical and Policy Implications

6.1. Theoretical Implications

This study supports the theory that integrating multiple nutrient sources enhances both crop productivity and economic sustainability, especially in low-input, high-acidity systems. It demonstrates how ecological nutrient management translates into tangible economic benefits.

6.2. Policy Implications

- Incentivizing Local Organic Inputs: Policy frameworks should support training and composting programs using locally available biomass like Eupatorium.
- INM Promotion through Extension: Government and ICAR schemes should integrate INM modules into Krishi Vigyan Kendras (KVKs) and FPO outreach.
- Support for Biofertilizer Adoption: Biofertilizer subsidies and quality assurance mechanisms are needed to promote reliable uptake by smallholders.

7. Conclusion

INM practices significantly improved the profitability of raising peanut in acidic soils. Among nine treatments, T_9 (RDF + *Eupatorium* + Rhizobium + PSB) emerged as the most economically viable and agronomically effective, with the highest B:C ratio and net return. The incorporation of locally available weed biomass as an organic input offers a sustainable pathway to reduce external input costs while improving soil health. These findings reinforce the value of diversified nutritional approach for smallholders in NEH region.

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