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Integrated nutrient management enhances growth, productivity and profitability of greengram (*Vigna radiata* L.) in rice fallow ecosystems of Eastern India

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Abstract

Rice fallow systems hold considerable potential for pulse cultivation, but yields are often limited due to inadequate nutrient management. A field experiment was conducted during the Rabi season of 2017-18 at OUAT, Bhubaneswar to assess the effect of foliar nutrient application on the growth, nodulation, and productivity of greengram (*Vigna radiata* L.) variety IPM 02-14 under rice fallow conditions. The experiment was laid out in a randomized block design with twelve treatments, combining basal fertilization (RDF: 20:40:20 N:P₂O₅:K₂O kg ha⁻¹) with foliar sprays of urea (2%), DAP (2%), and NPK (19:19:19, 2%) applied at 26 and 36 DAS.

Results indicated that RDF as basal combined with 2% NPK (19:19:19) foliar sprays at 26 and 36 DAS significantly improved all growth parameters, including plant height (37.13 cm), number of branches per plant (4.8), leaf area (71.6 cm² plant⁻¹), and dry matter accumulation (10.90 g plant⁻¹). This treatment also produced the highest seed yield of 676 kg ha⁻¹, representing a 133% increase over the control (290 kg ha⁻¹). However, the combination of RDF with 2% DAP foliar spray resulted in the highest net returns (₹18,644 ha⁻¹) and a benefit-cost ratio of 1.92.

The study demonstrates that integrated nutrient management, combining basal fertilization with foliar feeding, significantly enhances growth, productivity, and profitability of green gram in rice fallow systems.

Keywords: Rice fallow, foliar nutrition, growth parameters

1. Introduction

Rice fallow systems offer considerable potential for pulse cultivation in India, particularly in the eastern and southern regions, where about 11.65 million hectares remain fallow after rice harvest (Kumar *et al.*, 2018)^[6]. Cultivating greengram (*Vigna radiata* L.) in these rice fallow areas is a promising approach to increase pulse production, enhance overall system productivity, and maintain soil fertility through biological nitrogen fixation.

A major challenge in rice fallow pulse cultivation is the difficulty of applying nutrients through conventional soil methods due to relay cropping and limited residual soil moisture. Under such conditions, foliar nutrient application becomes critical for meeting crop nutritional needs during key growth stages (Ganapathy *et al.*, 2008)^[4]. Recent research highlights the importance of foliar feeding for short-duration crops, where soil-applied fertilizers may not be fully available before crop maturity (Kumar *et al.*, 2018)^[6].

Growth traits such as plant height, branching, leaf area development, and dry matter accumulation directly influence green gram yield and are strongly affected by nutrient availability during the vegetative stage. Integrating basal fertilization with targeted foliar nutrition can optimize these growth parameters. Despite its potential, rice fallow green gram productivity remains low (300-500 kg ha⁻¹), mainly due to nutrient management constraints. The relay cropping nature of these systems limits conventional soil fertilizer application, making foliar nutrition the primary strategy for supplementing nutrients during critical stages (Ganapathy *et al.*, 2008)^[4].

Although recent studies report positive effects of foliar nutrient application in pulses, comprehensive research on the growth, productivity, and profitability of rice fallow green gram under different foliar nutrient management strategies is still limited. This study tests the

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hypothesis that combining basal fertilization with foliar nutrient sprays enhances green gram growth, yield, and economic returns compared to using basal fertilization or foliar sprays alone.

2. Materials and Methods

2.1 Experimental Site and Design

The field experiment was carried out during the Rabi season of 2017-18 at the Instructional Farm of Orissa University of Agriculture and Technology (OUAT), Bhubaneswar, India, located at 20°15' N latitude, 85°52' E longitude, and 25.9 m above mean sea level. The site falls within the East and Southeastern Coastal Plain Agroclimatic Zone of Odisha, about 64 km from the Bay of Bengal.

The experiment was arranged in a randomized block design with three replications and twelve treatments. Each gross plot measured 5.65 m × 5.3 m, while the net plot area was 5.0 m × 5.0 m, with a plant spacing of 30 cm × 10 cm.

2.2 Soil Characteristics

The soil at the experimental site was sandy loam with a slightly acidic pH of 5.23. It was low in available nitrogen (182.1 kg ha⁻¹), medium in available phosphorus (16.2 kg ha⁻¹), and high in available potassium (298.4 kg ha⁻¹). The soil had an organic carbon content of 0.55%, a bulk density of 1.45 g cm⁻³, and a water-holding capacity of 37.5%.

2.3 Treatments and Crop Management

The treatments comprised different combinations of basal fertilization and foliar nutrient application:

- T₁: Recommended fertilizer dose (RDF) @ 20:40:20 N:P₂O₅:K₂O kg ha⁻¹
- T₂: 2% Urea spray at 26 and 36 DAS
- T₃: 2% DAP spray at 26 and 36 DAS
- T₄: 2% NPK (19:19:19) spray at 26 and 36 DAS
- T₅: T₁ + 2% Urea spray at 26 DAS
- T₆: T₁ + 2% DAP spray at 26 DAS
- T₇: T₁ + 2% NPK (19:19:19) spray at 26 DAS
- T₈: T₁ + T₂
- T₉: T₁ + T₃
- T₁₀: T₁ + T₄
- T₁₁: T₁ + Water spray at 26 and 36 DAS
- T₁₂: Control (no fertilizer)

The greengram variety IPM 02-14 was sown on 17 December 2017 at a seed rate of 20 kg ha⁻¹. Basal nutrients were applied according to the treatments using urea, di-ammonium phosphate (DAP), and muriate of potash (MOP). Foliar sprays were applied with a hand sprayer fitted with a conical nozzle at the pre-flowering stage (26 DAS) and again 10 days later (36 DAS).

3. Experimental observations

3.1 Pre harvest studies

3.1.1 Plant height

Plant height was recorded to assess the effect of different treatments on growth. Five tagged plants per plot were measured at 15 DAS and subsequently at 15-day intervals until maturity. Height was measured in centimeters from the soil surface to the apex of the main stem.

3.1.2 Branches per plant (no.)

The number of branches per plant was recorded on five tagged plants in each plot at 15 DAS and then at 15-day intervals until maturity.

3.1.3 Leaves per plant (no.)

Leaves were counted on five tagged plants per plot at 15 DAS and at 15-day intervals thereafter until maturity. The counts were averaged to express the number of leaves per plant.

3.1.4 Leaf area

For destructive sampling, all leaves were removed from the collected plants, and leaf area was measured using a leaf area meter. Fresh leaves were used for the measurements, and the readings were averaged to calculate the leaf area per plant.

3.1.5 Leaf area index

The leaf area index (LAI) was calculated by dividing the leaf area per plant by the area of land occupied by that plant, as shown below.

$$LAI = \frac{\text{Total leaf area}}{\text{Ground area}}$$

Total leaf area was found out by multiplying actual leaf area per plant with number of plants m⁻².

3.1.6 Dry matter production (g)

Dry matter per plant was measured from five randomly selected plants in the designated destructive sampling row of each plot at 15 DAS and at 15-day intervals until maturity using an electronic balance. The samples were first air-dried for two days and then oven-dried at 80°C until a constant weight was achieved.

3.1.7 Shoot dry weight (g)

Shoot dry weight was determined from five randomly selected plants per plot at 15 DAS and at 15-day intervals until maturity using an electronic balance. The samples were air-dried for two days and then oven-dried at 80°C until a constant weight was reached.

3.2 Post harvest studies

3.2.1 Pods per plant (no.)

The number of pods per plant was counted on five randomly selected plants from each plot just prior to harvest.

3.2.2 Seeds per pod (no.)

Pods from five randomly selected plants in each plot were harvested, carefully threshed by hand, and the average number of seeds per pod was determined.

3.2.3 Test weight (g)

From a representative grain sample of each plot, 100 grains were counted and weighed to determine the test weight in grams. Broken seeds were excluded, but shriveled grains were included in the count.

3.2.4 Seed yield (kg ha⁻¹)

The yield from each net plot was threshed separately to obtain clean seeds. Plot-wise seed yield was recorded after sun-drying the seeds to a standard moisture level, and then the yield was converted to kilograms per hectare (kg ha⁻¹).

3.2.5 Haulm yield (kg ha⁻¹)

Haulm yield was calculated by subtracting the seed yield per plot from the total bundle weight (biological yield) and then converting the result to kilograms per hectare (kg ha⁻¹).

3.2.6 Harvest index (%)

It was calculated by using the following formula

$$HI = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

Where, economic yield is the seed yield (kg ha⁻¹) and biological yield is the total above ground biomass (seed + haulm) yield in kg ha⁻¹.

3.3 Economics

The economics of the different treatments were calculated based on the prevailing market prices of inputs and produce during the study period.

3.3.1 Cost of cultivation (Rs. ha⁻¹)

Cost of cultivation is a key component in economic analysis. It can be determined by accounting for the prevailing market prices of inputs, labor wages, and the actual expenses incurred for various operations during the study.

3.3.2 Gross monetary returns (Rs. ha⁻¹)

Gross monetary returns represent the total income from the crop produce (seed plus haulm) expressed in ₹ ha⁻¹. These returns were calculated based on the prevailing market prices of the produce at the time of harvest.

3.3.3 Net monetary returns (Rs. ha⁻¹)

Net monetary returns (₹ ha⁻¹) were calculated by deducting the

total expenditure (₹ ha⁻¹) from the gross returns, essentially subtracting the cost of cultivation from the gross return. This represents the actual income earned by the farmer.

The net monetary returns for the different treatments were calculated using the following formula:

$$\text{Net monetary returns (Rs. ha}^{-1}\text{)} = \text{Gross returns (Rs. ha}^{-1}\text{)} - \text{Cost of cultivation (Rs. ha}^{-1}\text{)}$$

3.4 Statistical analysis

All biometric data collected from pre- and post-harvest studies were organized into appropriate tables and subjected to statistical analysis following the Randomized Block Design (RBD) procedure to generate the analysis of variance (ANOVA) table. Treatment differences were tested for significance using the 'F' test. The standard error of the mean (SEM ±) and the critical difference (CD) at the 5% significance level were calculated according to the formulas given by Gomez and Gomez (1984)^[5] for result interpretation.

4. Experimental Findings

4.1 Pre Harvest Studies

4.1.1 Plant height (cm)

The application of RDF as basal combined with 2% NPK (19:19:19) foliar sprays at 26 and 36 DAS (T₁₀) resulted in the maximum plant height of 37.13 cm, which was significantly higher than all other treatments. The corresponding data are presented in Table 1.

Table 1: Data of Green Gram influenced by nutrient management practices

Treatment	Plant height (cm)	No of Branches per Plant	No of Trifoliolate Leaves per Plant at 45 DAS	Leaf area cm ² per plant at 45 DAS	Leaf area index at 45 DAS	Shoot dry weight (g plant ⁻¹)	Total dry matter accumulation (g plant ⁻¹)
T ₁	32.27	3.80	8.53	755.60	2.52	8.60	8.94
T ₂	31.40	3.53	8.33	750.10	2.50	8.43	8.76
T ₃	31.53	3.47	8.33	751.80	2.51	8.47	8.78
T ₄	31.60	3.60	8.40	754.20	2.51	8.53	8.86
T ₅	33.33	4.13	8.67	782.80	2.61	9.33	9.70
T ₆	33.53	4.20	8.73	817.40	2.72	9.40	9.77
T ₇	33.87	4.27	8.80	822.73	2.74	9.43	9.81
T ₈	34.20	4.47	8.87	843.56	2.81	9.57	9.95
T ₉	35.47	5.13	9.73	893.82	2.98	9.90	10.33
T ₁₀	37.13	5.47	10.47	957.23	3.19	10.43	10.90
T ₁₁	32.63	4.13	8.60	763.03	2.54	8.73	9.09
T ₁₂	27.37	3.13	7.53	586.07	1.95	7.13	7.43
S.Em±	0.52	0.17	0.16	10.92	0.04	0.13	0.13
CD (P = 0.05)	1.52	0.48	0.48	32.02	0.11	0.37	0.38

4.1.2 Number of branches plant

At maturity, the treatment with RDF as basal and 2% NPK (19:19:19) foliar sprays at 26 and 36 DAS (T₁₀) produced the highest number of branches per plant (5.47), which was significantly greater than most other treatments, except T₉. The data are presented in Table 1.

4.1.3 Number of trifoliolate leaves per plant

The maximum number of leaves per plant (10.47) at 45 DAS was recorded with RDF as basal combined with 2% NPK (19:19:19) foliar sprays at 26 and 36 DAS (T₁₀), which was 39% higher than the control (7.53) and was closely followed by T₉. The data are presented in Table 1.

4.1.4 Leaf area per plant (cm²)

The highest leaf area per plant (957.2 cm²) at 45 DAS, later decreasing to 536.13 cm² at maturity, was recorded in the treatment with RDF as basal and 2% NPK (19:19:19) foliar

sprays at 26 and 36 DAS (T₁₀). This represented a 63.3% increase over the control treatment (586.07 cm²) at 45 DAS. The data are presented in Table 31.

4.1.5 Leaf area index

The highest LAI was recorded in plants fertilized with RDF as basal and NPK (19:19:19) 2% spray at 26 and 36 DAS (T₁₀) i.e. 3.19 at 45 DAS significantly superior to all other treatments showing an advantage of 63.6% over control treatment (1.95) at 45 DAS. The analyzed data is presented in Table 1.

4.1.6 Shoot dry weight (g plant⁻¹)

The maximum shoot dry weight at harvest (10.43 g plant⁻¹) was recorded in the treatment receiving RDF as basal along with 2% NPK (19:19:19) foliar sprays at 26 and 36 DAS (T₁₀), which was significantly higher than all other treatments. The minimum shoot weight (7.13 g plant⁻¹) was observed in the control. The data are presented in Table 1.

4.1.7 Total dry matter accumulation (g plant⁻¹)

The highest mean dry matter accumulation at harvest (10.90 g per plant) was recorded in the treatment with RDF as basal combined with 2% NPK (19:19:19) foliar sprays at 26 and 36 DAS (T₁₀), which was significantly greater than all other treatments. The lowest dry matter accumulation (7.43 g per plant) was observed in the control (T₁₂). The data are presented in Table 1.

4.2 Post harvest studies

4.2.1 Number of pods per plant

The maximum number of pods per plant (11.7) was observed with RDF as basal combined with 2% NPK (19:19:19) foliar sprays at 26 and 36 DAS (T₁₀), which was at par with T₈ and T₉ and significantly higher than the other treatments. The minimum number of pods (6.6) was recorded in the control (T₁₂). The data are presented in Table 2.

Table 2: Yield attributing characters, Seed yield (kg ha⁻¹), haulm yield (kg ha⁻¹) and harvest index of green gram at different stages as influenced by nutrient management practices

Treatment	Pods per plant (No.)	Seeds per pod (No.)	Pod length (cm)	Test weight (g)	Seed Yield	Haulm Yield	HI
T ₁	9.6	9.6	6.8	29.0	469.7	1361.9	25.6
T ₂	8.9	9.3	6.7	28.7	450.0	1337.5	25.2
T ₃	8.7	9.3	6.8	28.9	454.2	1345.3	25.3
T ₄	8.9	9.3	6.8	28.9	463.1	1348.9	25.6
T ₅	10.9	10.5	6.9	29.6	613.6	1513.6	27.9
T ₆	11.1	10.6	7.0	29.7	617.9	1526.2	28.9
T ₇	11.3	10.7	7.1	30.3	634.0	1548.9	29.1
T ₈	11.4	11.1	7.2	32.1	642.1	1562.5	29.2
T ₉	11.5	11.3	7.5	32.1	662	1605.5	29.2
T ₁₀	11.7	11.5	7.6	33.3	676.4	1634.1	29.3
T ₁₁	10.4	10.3	6.9	29.2	522.8	1382.5	27.5
T ₁₂	6.6	9.2	6.6	24.6	289.8	982.9	22.8
S.Em±	0.12	0.12	0.07	0.83	10.66	38.72	---
CD (P = 0.05)	0.3	0.4	0.2	2.4	31.3	113.6	---

4.2.2 Pod length (cm)

Data on pod length, presented in Table 2, showed that the longest pods (7.6 cm) were recorded with RDF as basal combined with 2% NPK (19:19:19) foliar sprays at 26 and 36 DAS (T₁₀), which was significantly higher than all other treatments except T₉. The shortest pods (6.6 cm) were observed in the control (T₁₂).

4.2.3 Number of seeds per pod

The data in Table 2 indicate that the highest number of seeds per pod (11.53) was recorded in the treatment with RDF as basal combined with 2% NPK (19:19:19) foliar sprays at 26 and 36 DAS (T₁₀), closely followed by T₉, and was significantly superior to all other treatments. The lowest number of seeds per pod (9.20) was observed in the control (T₁₂).

4.2.4 Test weight (g)

The highest test weight (33.3 g) was recorded in the treatment with RDF as basal and 2% NPK (19:19:19) foliar sprays at 26 and 36 DAS (T₁₀), closely followed by T₈ and T₉, and was significantly higher than the other treatments. The lowest test weight (24.6 g) was observed in the control (T₁₂).

4.2.5 Seed yield (kg ha⁻¹)

The seed yield data (kg ha⁻¹) presented in Table 2 showed that the highest seed yield of 676.4 kg ha⁻¹ was achieved with RDF as basal combined with 2% NPK (20:20:20) foliar sprays at 26 and 36 DAS (T₁₀), which was significantly superior to all other nutrient management practices except T₉ (662 kg ha⁻¹). This best nutrient management practice resulted in a yield increase of approximately 44% over RDF alone (T₁) and 133% over the unfertilized control (289.8 kg ha⁻¹).

4.2.5 Haulm yield (kg ha⁻¹)

The highest haulm yield (1,634 kg ha⁻¹) was obtained with RDF as basal combined with 2% NPK (19:19:19) foliar sprays at 26 and 36 DAS (T₁₀), which was significantly higher than most other treatments, except T₉, T₈, T₇, and T₆. The lowest haulm yield (983 kg ha⁻¹) was recorded in the control (T₁₂).

4.2.5 Harvest index

The data on harvest index (HI) in Table 2 revealed that the highest HI (29.3%) was obtained with RDF as basal combined with 2% NPK (19:19:19) foliar sprays at 26 and 36 DAS (T₁₀), while the lowest HI (22.8%) was recorded in the unfertilized control (T₁₂).

Table 3: Economics of green gram as influenced by nutrient management practices

Treatment	Cost of cultivation	GMR	NMR	B:C
T ₁ : RDF(20:40:20 kg N:P ₂ O ₅ :K ₂ O /ha) as basal	18892	27878	8986	1.48
T ₂ : Urea @2% at 26 and 36 DAS	16618	26758	10140	1.61
T ₃ : DAP @2% at 26 and 36 DAS	16980	26997	10017	1.59
T ₄ : 19:19:19(NPK) @2% at 26 DAS	18700	27492	8792	1.47
T ₅ : RDF + Urea @2% at 26 DAS	19351	36018	16667	1.86
T ₆ : RDF + DAP @2% at 26 DAS	19532	36272	16740	1.86
T ₇ : RDF + 19:19:19(NPK) @2% at 26 DAS	20592	37193	16601	1.81
T ₈ : RDF + Urea @2% at 26 and 36 DAS	19810	37659	17849	1.90
T ₉ : RDF + DAP @2% at 26 and 36 DAS	20172	38816	18644	1.92
T ₁₀ :RDF+19:19:19(NPK) @2% at 26 and 36 DAS	21892	39653	17761	1.81
T ₁₁ : RDF+ water spray	19692	30828	11136	1.56
T ₁₂ : Absolute control	16300	17413	1113	1.07

4.3. Economics

A detailed analysis of the economics of different nutrient management practices in greengram showed that net monetary returns ranged from ₹1,113 to ₹18,644 ha⁻¹. The highest net return (₹18,644 ha⁻¹) was achieved with RDF as basal combined with two foliar sprays of 2% DAP at 26 and 36 DAS, closely followed by similar treatments with 2% urea (₹17,849 ha⁻¹) and 2% NPK (19:19:19) (₹17,761 ha⁻¹) applied twice on the same days. The additional two foliar sprays of 2% DAP nearly doubled the profit compared to RDF alone. The maximum benefit-cost (B:C) ratio of 1.92 was also observed with this treatment, closely followed by RDF as basal plus two sprays of 2% urea at 26 and 36 DAS (T₈).

5. Discussion

5.1 Plant height

Nutrient application significantly influenced the plant height of greengram compared to the control. The increase in height was attributed to internode elongation and vigorous root development. The tallest plants (37.13 cm) were recorded in T₁₀, closely followed by T₉. These findings are consistent with Kumar *et al.* (2018) [6], who reported increased plant height in black gram with RDF (20:40:40) and 2% NPK (19:19:19) foliar spray at flowering, and are also in agreement with the results of Thakur *et al.* (2017) [12].

5.2 Branches per plant

The number of branches per plant was significantly higher in T₁₀ compared to other treatments, except T₉. The increase in branching was attributed to the combined effect of RDF as basal and two foliar applications of 2% NPK (19:19:19), which enhanced various metabolic processes such as photosynthesis, energy transfer, and symbiotic nitrogen fixation. The greater number of branches and increased plant height may be due to the higher availability of nitrogen, phosphorus, and potassium, which play a crucial role in cell division.

5.3 Number of trifoliolate leaves per plant, leaf area and LAI

In the present study, the number of leaves per plant increased steadily up to 45 DAS and then declined sharply. The highest leaf area per plant (957.2 cm²) and leaf area index (LAI) of 3.19 were recorded at 45 DAS when RDF was applied as basal along with two 2% foliar sprays of NPK (19:19:19) at 26 and 36 DAS. Similar findings were reported by Thakur *et al.* (2017) [12] and Bansal and Ahmad (2015) [1] in greengram with RDF and two foliar sprays, as well as by Sritharan *et al.* (2005) [10] and Senthilkumar *et al.* (2008) [8] in black gram.

5.4 Dry matter accumulation per plant

The growth parameters indicated that plants receiving RDF as basal along with 2% NPK (19:19:19) foliar sprays at 26 and 36 DAS exhibited maximum growth. At harvest, this treatment recorded the highest dry matter accumulation per plant (10.9 g), which was significantly superior to all other treatments. The enhanced growth and development could be attributed to the adequate supply of nitrogen, phosphorus, and potassium through basal and foliar applications during flower initiation and pod formation. This likely maintained higher auxin levels for increased plant height, larger leaf area, and higher chlorophyll content, improving light interception, absorption, and utilization, thereby boosting photosynthetic rates and dry matter accumulation. These results are in agreement with the findings of Thakur *et al.* (2017) [12] and Takankhar *et al.* (2017) [11]. Foliar application at later growth stages may have also facilitated

effective nutrient translocation within the plant (Kumar *et al.*, 2015) [7].

5.5 Yield attributes

The number of pods per plant is a key yield-determining trait, directly influencing per-plant and per-area production. The highest number of pods per plant (11.7), longest pod length (7.6 cm), maximum seeds per pod (11.5), and highest test weight (33.3 g) were recorded with RDF as basal combined with two foliar sprays of 2% NPK (19:19:19) (Table 2). Similar results were observed with RDF plus two foliar sprays of 2% DAP, which produced 11.5 pods, 7.5 cm pod length, 11.3 seeds per pod, and 32.1 g test weight. These improvements may be attributed to the combined effect of basal and foliar nutrients meeting the crop's critical nutrient requirements, as well as reduced flower and fruit shedding, enhancing the source-sink translocation of photosynthates. Similar findings were reported by Uma Maheswari *et al.* (2017) [13] and Thakur *et al.* (2017) [12].

5.6 Yield

Foliar application of different nutrients significantly influenced the seed yield of greengram. The highest seed yield (676 kg ha⁻¹) and haulm yield were recorded with RDF as basal combined with 2% NPK (19:19:19) foliar sprays at 26 and 36 DAS, which was comparable to RDF as basal with 2% DAP or Urea sprays at the same intervals and significantly higher than the remaining treatments. In pulse crops, nutrients are rapidly translocated from source leaves to developing pods, leading to leaf senescence and nodule degeneration. Foliar feeding helps to overcome these limitations by stimulating root growth, enhancing energy transformation, increasing metabolic activities, and improving pod setting. This likely contributed to the observed improvements in growth, development, and yield in the present study. Similar findings were reported by Uma Maheswari *et al.* (2017) [13].

5.7 Economic

The cost of cultivation for greengram in rice fallow varied from Rs. 16,300 to Rs. 21,892 ha⁻¹, depending on the nutrient management practice. The highest cost (Rs. 21,892 ha⁻¹) was recorded for RDF as basal combined with two foliar sprays of 2% NPK (19:19:19). Gross returns ranged from Rs. 17,413 to Rs. 39,653 ha⁻¹, resulting in net returns of Rs. 1,113 to Rs. 18,644 ha⁻¹. The highest net return (Rs. 18,644 ha⁻¹) was obtained with RDF as basal plus two foliar sprays of 2% DAP at 26 and 36 DAS, followed by RDF as basal with two foliar sprays of 2% urea (Rs. 17,849 ha⁻¹). The lowest gross and net returns were observed in the unfertilized control (Rs. 16,300 and Rs. 1,113 ha⁻¹, respectively).

Similarly, the highest benefit-cost (B:C) ratio of 1.92 was achieved with RDF as basal and two 2% DAP foliar sprays, followed by RDF as basal with two 2% urea sprays (1.90), while the control had the lowest B:C ratio (1.07). The slightly lower net return and B:C ratio with RDF plus NPK foliar sprays were due to the higher cost of NPK fertilizer. These results align with previous studies reporting improved grain yield, net income, and B:C ratio with basal RDF combined with two 2% DAP foliar applications at 26 and 36 DAS, as observed by Kumar *et al.* (2018) [6], Shashikumar *et al.* (2013) [9], Vinothkumar *et al.* (2013) [14], Dixit and Elamathi (2007) [3], and Chandrasekhar and Bangarumusamy (2003) [2].

6. Summary and Conclusion

A field experiment was conducted during the Rabi season of

2017-18 at the Instructional Farm of Orissa University of Agriculture and Technology (OUAT), Bhubaneswar, to evaluate the effect of nutrient management on greengram (*Vigna radiata* L.) in rice fallow. Twelve treatments were tested: T₁ - RDF @ 20:40:20 (N:P₂O₅:K₂O), T₂ - Urea @ 2% foliar spray at 26 and 36 DAS, T₃ - DAP @ 2% foliar spray at 26 and 36 DAS, T₄ - NPK (19:19:19) @ 2% foliar spray at 26 and 36 DAS, T₅ - T₁ + Urea @ 2% spray at 26 DAS, T₆ - T₁ + DAP @ 2% spray at 26 DAS, T₇ - T₁ + NPK (19:19:19) @ 2% spray at 26 DAS, T₈ - T₁ + T₂, T₉ - T₁ + T₃, T₁₀ - T₁ + T₄, T₁₁ - T₁ + water spray at 26 and 36 DAS, and T₁₂ - absolute control. The experiment was laid out in a randomized block design with three replications. The experimental soil was sandy loam, slightly acidic (pH 5.23), low in available nitrogen (182.1 kg ha⁻¹), medium in phosphorus (16.2 kg ha⁻¹), and high in potassium (298.4 kg ha⁻¹). Greengram variety IPM 02-14 was sown on 17 December 2017 and harvested on 18 February 2018. Various growth and yield-contributing characters were recorded to assess seed and haulm production.

Summary

- Growth Parameters:** Plant growth was significantly influenced by the different treatments. The highest plant height (37.13 cm), number of branches per plant (5.47), leaf number (10.47), leaf area (957.2 cm²), leaf area index (3.19), and dry matter accumulation (10.90 g plant⁻¹) were recorded with basal application of RDF combined with 2% NPK (19:19:19) foliar spray at 26 and 36 DAS.
- Yield Attributes:** Number of pods per plant, pod length, seeds per pod, and test weight were significantly affected by the treatments. The maximum values—pods per plant (11.7), pod length (7.6 cm), seeds per pod (11.53), and test weight (33.3 g)—were recorded under RDF as basal plus 2% NPK (19:19:19) foliar spray at 26 and 36 DAS.
- Yield and Harvest Index:** Seed yield, haulm yield, and harvest index were significantly influenced by nutrient management. RDF as basal combined with 2% NPK (19:19:19) spray at 26 and 36 DAS produced the highest seed yield (676 kg ha⁻¹), haulm yield (1634 kg ha⁻¹), and harvest index (29.3%), while the lowest values (seed yield 290 kg ha⁻¹, haulm 983 kg ha⁻¹, harvest index 22.8%) were observed in the control (T₁₂).
- Economics:** The maximum net profit of Rs. 18,644 ha⁻¹ with a benefit-cost (B:C) ratio of 1.92 was obtained with RDF as basal plus 2% DAP foliar spray at 26 and 36 DAS, whereas the minimum net profit (Rs. 1,113 ha⁻¹) with B:C ratio 1.07 was recorded in the control.

Conclusion

The study concluded that RDF (20:40:20 N:P₂O₅:K₂O) as basal along with 2% NPK (19:19:19) foliar spray at 26 and 36 DAS produced the maximum seed yield (676 kg ha⁻¹), while RDF as basal with 2% DAP foliar spray provided the highest net return (Rs. 18,644 ha⁻¹) with a comparable yield of 662 kg ha⁻¹.

Suggestions for further work

It is recommended that this experiment be repeated over a minimum of three years to validate and confirm the findings of the present study.

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