



RESEARCH ARTICLE

Comparative evaluation of foliar feeding approaches on growth, yield and economics of irrigated red gram (*Cajanus cajan* (L.) Millspaugh)

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Abstract

Reduction in pulse production is often attributed to excessive flower drop and poor pod setting during the reproductive phase. This loss is mainly caused by nutrient deficiencies or hormonal imbalance or combined effect of factors environmental stress. Foliar application of balanced nutrients/hormonal imbalance effectively minimise flower drop by improving plant nutrition and hormonal balance. As a result, it enhances pod formation and ultimately boosts overall yield in pulse crops. A field experiment was conducted during the rabi (2023–24) at the experimental farm, School of Agricultural Sciences, Karunya Institute of Technology and Sciences, Coimbatore. The experiment was conducted in randomized block design (RBD) with 8 treatments and it was replicated thrice. The results shows that application of 100 % recommended dose of fertiliser (RDF) + 12.5 t ha⁻¹ farmyard manure (FYM) + foliar application of 5 kg Tamil Nadu Agricultural University (TNAU) pulse wonder per hectare mixed with 500 L of water applied during the flowering stage registered higher growth parameter, yield attributes and economic analysis.

Keywords: foliar feeding; salicylic acid; Tamil Nadu Agricultural University pulse wonder; parametric budgeting

Introduction

Pulse production is essential for food security offering a rich source of protein and nutrients especially in vegetarian diets. It enhances soil fertility through nitrogen (N) fixation and promoting sustainable farming. According to Ministry of Agriculture and Farmer's Welfare (MoAFW) India is the top producer and consumer of pulses (1). In 2023–24, the country recorded a total pulse cultivation area of 27.51 Mt (Million tonnes) with yield about 24.25 million tonnes of production with a productivity of 881 kg per hectare (2). In India, red gram is grown in the central and southern states including Maharashtra, Madhya Pradesh, Chhattisgarh, Gujarat, Telangana, Andhra Pradesh, Karnataka and Tamil Nadu. These areas are characterised by medium to deep soils and the crop is largely cultivated under rain-fed conditions (3). Red gram is a rich source of protein, fibre, vitamins and it is naturally low in fat and sodium. These qualities make it especially important in the diets of India's predominantly vegetarian population. It is the most extensively grown pulse crops commonly cultivated across tropical and subtropical regions and is highly valued for its resilience to drought conditions. Red gram is predominantly cultivated under rainfed conditions by farmers which often leads to moisture stress during critical growth stages and limits yield potential. Adoption of irrigated conditions even as protective or supplemental irrigation ensures better soil moisture availability during flowering

and pod development. Inadequate nutrient uptake weakens the plant development, leading to stunted growth, poor flowering results in lower yields. Low nutrient absorption by plants is a major factor that can lead to reduced crop yields. When the essential nutrients are not properly taken up by the plant it affects the physiological processes of the plants. Among different nutrient application methods, foliar feeding has proven effective as nutrients enter through the leaf surface or stomata, enabling faster absorption and utilisation by plants. Foliar feeding is especially advantageous for early-maturing crops and can be integrated with routine plant protection measures. The use of foliar nutrition helps lower cultivation costs by reducing the need for fertilisers, minimising nutrient loss and promoting more economical crop production. The study was conducted to evaluate influence of various foliar application in the growth and yield of red gram (*Cajanus cajan* (L.) Millspaugh) and its to assess the economics of various foliar feeding approach.

Materials and Methods

Experimental site

The study was conducted at the experimental farm, Karunya Institute of Technology and Sciences, Coimbatore which is situated 474 MSL at 10°55' N latitude and 76°44' E longitude in the western

part of Tamil Nadu. During the rabi season of 2023–24 a field experiment was conducted to assess the impact of different foliar application of plant nutrients and growth regulators on red gram growth, yield and economics. The experimental soil was classified as a silty clay loam with a pH of 8.10, an electrical conductivity of 0.28 dS m⁻¹ an organic carbon content of 0.41 % and 312 kg ha⁻¹ of N, 15.2 kg ha⁻¹ of P₂O₅ and 187 kg ha⁻¹ of K₂O.

Experimental design and treatments

The experiment was designed using a randomized block design (RBD) with 3 replications and 8 foliar treatments. The treatments included: T₁ - 100 % recommended dose of fertiliser (RDF) + 12.5 t ha⁻¹ of farmyard manure (FYM) + 2 % diammonium phosphate (DAP) spray; T₂ - 100 % RDF + 12.5 t ha⁻¹ FYM + 2 % urea spray; T₃ - 100 % RDF + 12.5 t ha⁻¹ FYM + 40 ppm naphthaleneacetic acid (NAA) spray; T₄ - 100 % RDF + 12.5 t ha⁻¹ FYM + 10 ppm salicylic acid; T₅ - 100 % RDF + 12.5 t ha⁻¹ FYM + 75 ppm GA₃; T₆ - 100 % RDF + 12.5 t ha⁻¹ FYM + 5 kg Tamil Nadu Agricultural University (TNAU) pulse wonder; T₇ - 100 % RDF + 12.5 t ha⁻¹ FYM and T₈ - control.

Crop management and statistical analysis

The red gram variety APK1 with a growth duration of 90–105 days was selected and sown at a seed rate of 15 kg ha⁻¹ with the spacing of 45 × 20 cm. A full dose of the recommended fertilisers (25 : 50 : 20 kg N P₂O₅ K₂O respectively) along with 12.5 t ha⁻¹ FYM was uniformly applied across all plots except for the control. The preparation and application of various foliar feeding approaches and plant growth regulators were given in Table 1. The data were analysed statistically using ANOVA (4).

Results and Discussion

Effect of foliar feeding in the growth attributes of red gram

The growth attributes like plant height, number of branches and dry matter production (DMP) recorded at the harvest stage were presented in Table 2. The growth parameter was influenced by the

foliar application in the growth of red gram. The result shows that higher plant height (111.5 cm), number of branches (14.67 per plant), DMP (4697 kg ha⁻¹) were recorded in the application of 100 % RDF + 12.5 t ha⁻¹ FYM + 5 kg TNAU pulse wonder and it was followed by the application of 100 % RDF + 12.5 t ha⁻¹ of FYM + 2 % DAP spray and the least observation was recorded in the control. The balanced mix of nutrients and growth promoters stimulated cell division and photosynthesis results in higher branching, improved canopy development, supporting better biomass accumulation. The rise in dry matter indicates efficient nutrient utilisation during critical growth stages. This result is in accordance with previous findings (5–7).

Effect of foliar feeding in the leaf area index of red gram

The leaf area index (LAI) influenced by the various foliar application in red gram at the stage of 30, 60, 90 DAS and harvest stage respectively were presented in Fig. 1. At 30 DAS, there is no significant differences were observed among the treatments and there is a minimal variation in early plant response. Whereas, in 60, 90 DAS and at harvest stage, various foliar application influenced the LAI under application of 100 % RDF + 12.5 t ha⁻¹ FYM + 5 kg TNAU pulse wonder resulted higher LAI followed by the application of 100 % RDF + FYM 12.5 t ha⁻¹ + 2 % of DAP and the lowest was recorded in the control plot. There were no significant differences in LAI at early days indicating little change in early plant response to treatments. However, at the reproductive stage there is significant increase in LAI showed better plant growth with the foliar application of TNAU pulse wonder compared with the 100 % RDF + FYM. This could be attributed to increased availability of nutrients as well as increased physiological activity. The findings are similar with (8).

Agronomic use efficiency influenced by foliar feeding on red gram

Agronomic use efficiency (AUE) is the increase of yield per unit of nutrient applied and is an important metric of fertiliser performance. The applied fertilisers increase the AUE by enhancing nutrient uptake, reducing losses and ensuring the nutrient is targeted to the plant tissue. The AUE of the red gram was influenced by various foliar

Table 1. Application methods of various plant growth regulators

Treatment	Preparation	Application stage
2 % DAP solution	Soaked 20 g DAP in one litre of water for 12 hr; Use supernatant as stock solution	At flowering stage and 15 days after flowering
2 % Urea solution	Dissolved 20 g of urea in 1 L water	At flowering stage and 15 days after flowering
40 ppm NAA solution	Mixed 40 mg of NAA in 1 L water	At pre-flowering stage and 15 days after first application
10 ppm salicylic acid	Mixed 10 mg of salicylic acid in 1 L of water	At pre-flowering stage and 15 days after first application
75 ppm GA₃ solution	Mixed 75 mg of gibberellic acid (GA ₃) in 1 L of water	At flowering and pod initiation stages
TNAU pulse wonder	Mixed 0.5 kg of TNAU pulse wonder in 500 mL of water	At flower initiation stage

TNAU: Tamil Nadu Agricultural University; NAA: naphthaleneacetic acid; DAP: diammonium phosphate.

Table 2. Effect of foliar application in the growth character of red gram

Treatments	Plant height (cm)	No of branches	DMP (kg ha ⁻¹)
T1	103.2	13.33	4145
T2	93.6	11.33	3324
T3	102.3	13.00	3992
T4	102.9	13.33	4082
T5	94.0	11.67	3432
T6	111.5	14.67	4697
T7	85.3	9.67	2740
T8	77.1	8.33	2169
SE(d)	3.8	0.61	542
CD (p = 0.05)	8.2	1.31	4145

DMP: dry matter production.

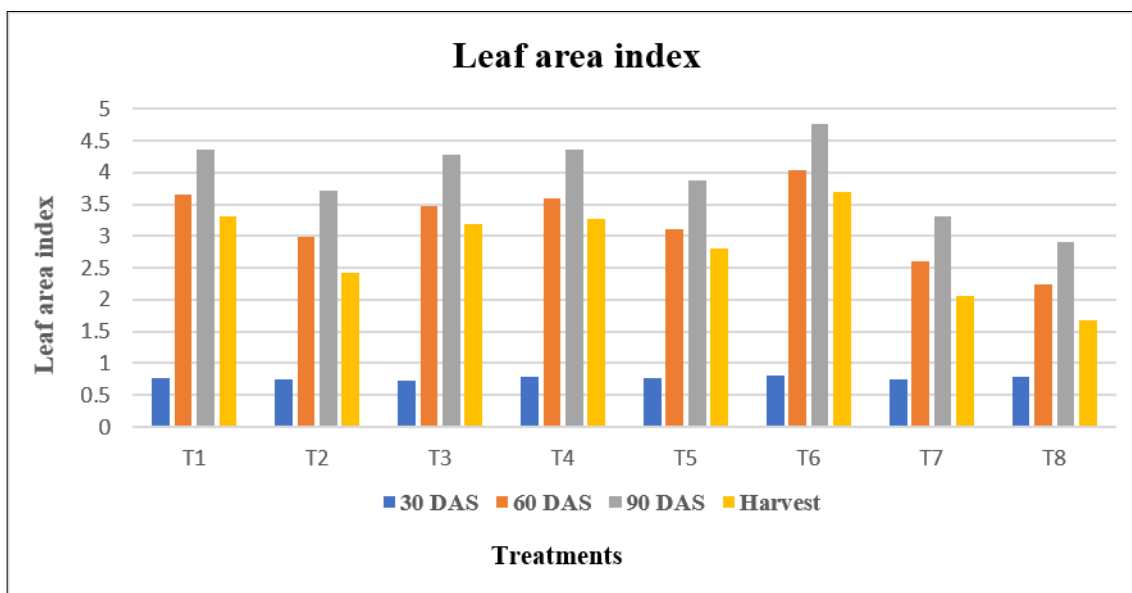


Fig. 1. Effect of foliar feeding in the leaf area index.

DAS: days after sowing.

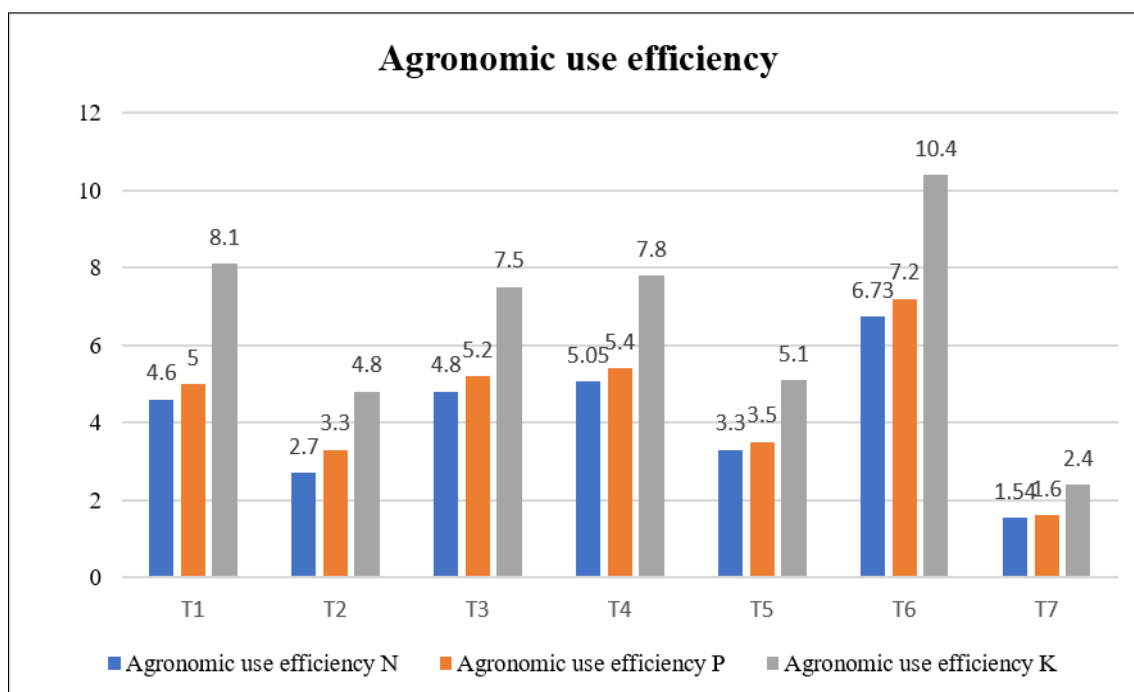


Fig. 2. Effect of foliar feeding on agronomic use efficiency.

N: nitrogen; P: phosphorous; K: potassium.

applications were given in Fig. 2. Vague of various foliar feeding approaches, the higher AUE of N was recorded with the application of 100 % RDF + FYM 12.5 t ha⁻¹ + TNAU pulse wonder followed by 100 % RDF + FYM 12.5 t ha⁻¹ + 10 ppm salicylic acid and the lowest was observed with 100 % RDF + FYM 12.5 t ha⁻¹. Similarly in phosphorus (P) and potassium (K), the application of 100 % RDF + FYM 12.5 t ha⁻¹ with TNAU pulse wonder resulted in the higher AUE. The lowest was recorded with the application of 100 % RDF + FYM 12.5 t ha⁻¹. Using pulse wonder, a foliar formulation with growth-promoting substances and micronutrients, shows potential to improve the AUE of red gram and therefore, partitioning of assimilates and grain formation. The improvement in AUE may also be attributed to the role of salicylic acid in promoting nutrient translocation and decreasing abiotic stress tolerance (9).

Effect of foliar feeding on nutrient uptake (kg/ha) at harvest stage

The nutrient uptake influenced by the various foliar feeding approaches were presented in Table 3. The foliar application of 100 % RDF + 12.5 t ha⁻¹ FYM + 5 kg TNAU pulse wonder recorded higher nutrient uptake N (47.89), P (28.99), K (25.89) and it was followed with application of 2 % DAP with 100 % RDF + FYM 12.5 t ha⁻¹. The lowest nutrient absorption was recorded in the control plot. The formulation of TNAU pulse wonder possibly improved the absorption of nutrients through the leaf surface and internal translocation of nutrients therefore representing an important influence in improving uptake during key growth phases. It contains plant growth regulators and micronutrients which may have stimulated enzyme activity in the roots and increased root

Table 3. Effect of foliar application on nutrient uptake (kg ha⁻¹) at harvest

Treatments	Nitrogen uptake	Phosphorous uptake	Potassium uptake
T1	43.19	26.14	23.62
T2	36.81	21.93	19.84
T3	42.43	25.49	22.73
T4	42.94	25.63	23.41
T5	37.73	22.64	20.03
T6	47.89	28.99	25.89
T7	32.11	19.08	17.58
T8	27.41	16.23	15.32
SE(d)	2.18	2.81	1.05
CD ($p = 0.05$)	4.68	6.89	2.25

activity which could promote more efficient P absorption from the soil. The role of foliar feeding as a supplement to improve use efficiency of nutrients. In comparison, the control plot highlighting the potential for soil-based nutrient supply as not enough in red gram production. These findings are relevant with early findings (10–12).

Effect of foliar feeding in the yield attributes of red gram

The yield attributes such as pods per plant, grains per pod, pod weight, grain and haulm yield (kg ha⁻¹) were significantly influenced by the various foliar feeding approaches that were presented in Table 4. Among the various treatment the application of 100 % RDF + 12.5 t ha⁻¹ FYM + 5 kg TNAU pulse wonder recorded higher yield characters such as 53.35 pods plant⁻¹, 4.27 grains pod⁻¹, 0.46 g pod weight, 1043 kg ha⁻¹ grain yield and 3452 kg ha⁻¹ haulm yield and it was followed by the application of 100 % RDF+ 12.5 t ha⁻¹ of FYM + 2 % DAP spray. The adequate and timely supply of essential nutrients particularly during the flower initiation and pod formation stages both of which are critical for reproductive success. This targeted nutrient availability contributed to a notable increase in the number of pods per plant and ultimately improved grain yield. Nutrient application through pulse wonder appears to have influenced the crop physiological process by shifting resource allocation from vegetative growth toward reproductive development. This balance is vital as it ensures that the plant invests more energy in pod and grain production rather than excess foliage.

Table 4. Effect of foliar application in the yield character of red gram

Treatment	No. of pods plant ⁻¹	No. of grains pod ⁻¹	Pod weight (g plant ⁻¹)	Grain yield (kg ha ⁻¹)	Haulm yield (kg ha ⁻¹)
T1	48.26	4.13	0.42	910	3031
T2	40.37	4.27	0.39	723	2395
T3	46.29	4.24	0.41	879	2910
T4	46.97	4.13	0.41	895	2983
T5	41.2	4.27	0.40	745	2482
T6	53.35	4.27	0.46	1043	3452
T7	35.28	4.27	0.39	588	1949
T8	30.19	4.12	0.35	453	1511
SE(d)	2.36	0.3	0.026	61	192
CD ($p = 0.05$)	5.05	NS	0.056	131	411

Table 5. Effect of foliar application in the economic evaluation of red gram

Treatments	Total cost of cultivation (₹)	Gross return (₹)	Net return (₹)	Economic B : C ratio	Agronomic B:C ratio
T1	108077	92514	-15563	0.86	-0.14
T2	108039	73477	-34562	0.68	-0.32
T3	108213	89327	-18886	0.83	-0.17
T4	108328	91086	-17242	0.84	-0.16
T5	110028	75739	-34289	0.69	-0.31
T6	103563	105989	2426	1.02	0.02
T7	102263	59758	-42505	0.58	-0.42
T8	45680	46152	472	1.01	0.01

These findings were also supported by previous results (13, 14).

Effect of foliar feeding on economics of red gram

The economic analysis of different treatments is summarised in Table 5. Economic indicators such as total cost of cultivation, gross return, net return, economic B : C ratio and agronomic B : C ratio were computed using the current market prices. The highest cost of cultivation (₹110026) was recorded in the foliar application of 100 % RDF + 12.5 t ha⁻¹ FYM + 75 ppm GA₃ and the least was observed in the control treatment. The higher gross return (₹105989), net return (₹2426), economic B : C ratio (1.02) and agronomic B : C ratio (0.02) was recorded in the application of 100 % RDF + 12.5 t ha⁻¹ FYM + 5 kg TNAU pulse wonder and the lowest economic analysis observations were recorded in the control plot. These findings are similar with early findings (15, 16).

Parametric budgeting and sensitivity analysis

The economic parameters varied across treatments were given in Table 5 and sensitivity analysis were presented in Fig 3. The higher material cost (₹83328 ha⁻¹) was recorded in the integrated application of 100 % RDF + FYM 12.5 t ha⁻¹ + 40 ppm NAA, followed by T₂ and T₁. The lowest main cost (₹31255 ha⁻¹) was observed in TNAU pulse wonder due to low input costs. Application of 100 % RDF + FYM 12.5 t ha⁻¹ + 5 kg ha⁻¹ TNAU pulse wonder had lower returns above variable cost (RAVC), but better economic performance measures including financial profitability were recorded in 10 ppm salicylic

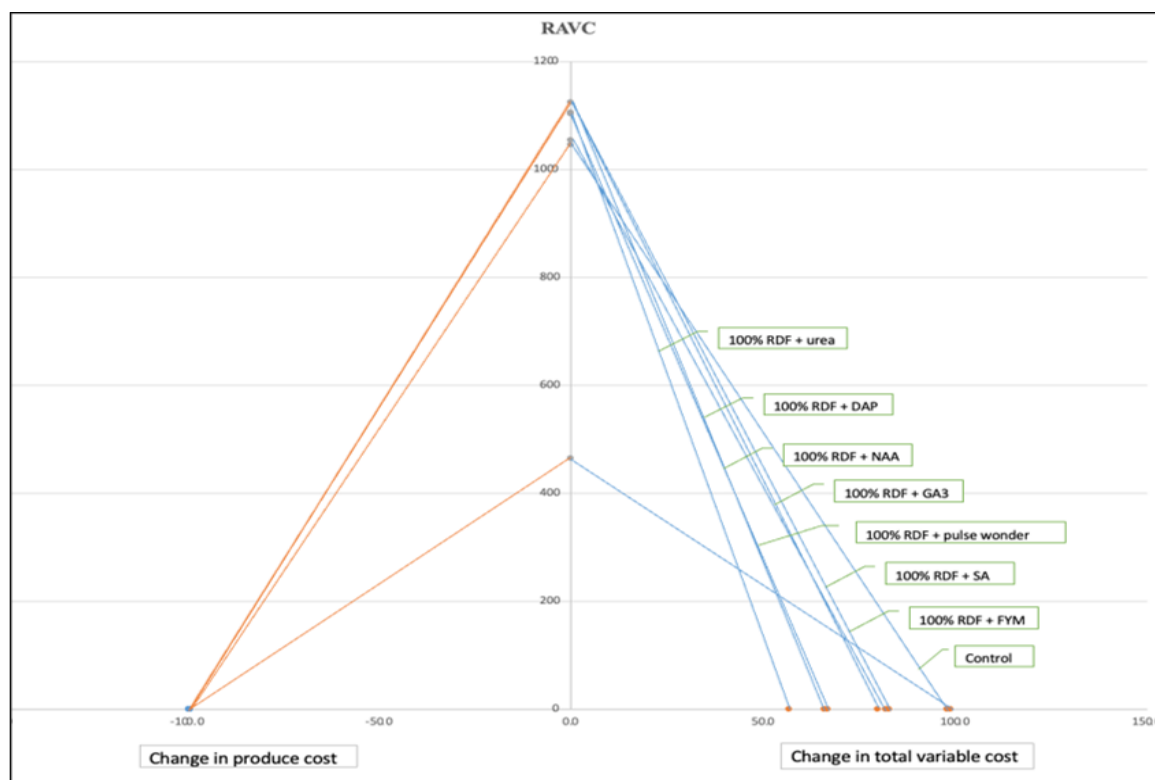


Fig. 3. Sensitivity analysis as influenced by different foliar feeding techniques at various growth stage of red gram.

RAVC: return above variable cost; RDF: recommended dose of fertiliser; DAP: diammonium phosphate; NAA: naphthaleneacetic acid; FYM: farmyard manure; SA: salicylic acid; GA₃: gibberlic acid.

Table 5. Parametric budgeting as influenced by different foliar feeding techniques of red gram

Treatments	GY 1	GR 2	MC 3	LC 4	ICC 5	TVC 6 (3+4+5)	RAVC 7 (2-6)	RMC 8 (2-4/4)	RLC 8 (2-3/4)	MBCR 10 (2/6)	BEP 11	Increase over BEP percent
T1	910	92514	81377	26700	3152	111229	110319	0.81	0.4	0.83	1661	-45.21
T2	723	73477	81339	26700	3151	111190	110467	0.58	-0.3	0.66	1661	-56.46
T3	879	89327	81513	26700	3156	111369	110490	0.77	0.3	0.80	1662	-47.12
T4	896	91086	81628	26700	3160	111488	110592	0.79	0.4	0.82	1664	-46.14
T5	745	75739	83328	26700	3209	113237	112492	0.59	-0.3	0.67	1682	-55.71
T6	1043	105989	80228	23335	3021	106584	105541	1.03	1.1	0.99	1612	-35.30
T7	588	59758	79728	22535	2983	105246	104658	0.47	-0.9	0.57	1598	-63.20
T8	454	46152	23430	22250	1332	47012	46558	1.02	1.0	0.98	495	-8.26

GY: grain yield; GR: gross return; MC: material cost; LC: labour cost; RAVC: return above variable cost; RMC: return on material cost; ICC: interest on capital; TVC: total variable cost; RLC: return on labour cost; MBCR: marginal benefit-cost ratio; BEP: breakeven point.

acid, for the higher RAVC (₹105541 ha⁻¹) with higher MBCR (0.99) and lowest negative percentage change in RAVC (-35.3 %) suggesting better economic performance and efficiency. Integrating TNAU pulse wonder with 100 % RDF + FYM 12.5 t ha⁻¹ + 5 kg ha⁻¹ had only a lower absolute return, but an effective marginal benefit-cost ratio (MBCR) measure (0.98) under the same resource conserving situation. T4 and T6 were economically viable treatments, while T5 (GA₃) and T3 (NAA) had low returns above variable costs and much more negative percentage changes (-63.2 % and -55.71 % respectively), meaning weaker economic performance with respect to profitability below variable costs. The treatment with the lowest break-even point (BEP) was T6 (₹ 495 ha⁻¹) showing that harvesting yield recoveries would be quicker than any other treatment above the fixed cost break-even point. Comparable results were observed in early results (17, 18).

Conclusion

The application of farmyard manure (FYM) with 5 kg of Tamil Nadu Agricultural University (TNAU) pulse wonder mixed with 500 L at flowering stage significantly improved the plant height, branching, dry matter production, increased the pod number, grain yield and better economical profits in the production of red gram. The synergy between nutrients and balanced foliar feeding approach nutrition played a vital role in boosting crop performance. This integrated approach not only supported better nutrient availability but also enhanced physiological efficiency during critical growth stages. The findings highlight the importance of combining organic and foliar inputs for sustainable pulse cultivation. The TNAU pulse wonder + FYM treatment can be recommended as an effective strategy for improving red gram productivity.

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Authors' contributions

KUK conducted the literature survey and contributed to the drafting of sections on effect on foliar feeding on cultivation practices of red gram. KUK contributed to the section on comparison in the regular fertilisers and foliar spraying. TSP supported the drafting and editing of the manuscript. KUK, RS and RM participated in structuring the manuscript and reviewed critical references. KS conceived of the review topic, guided the overall structure and scientific direction and coordinated the writing process. All authors have read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors used *Google Scholar* for literature search and *Paperpal* for language editing and grammar enhancement. After using these tools/services, the authors reviewed and edited the content as needed and takes full responsibility for the content of the publication.

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