

Economic Analysis of IPM in Bengal Gram Cultivation under Rainfed Conditions of Dharwad District, Karnataka

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ABSTRACT

Sustainable pulse production in India has been facing major challenges due to climate variability, high frequency of occurrence of pests and over-reliance on chemical pesticides. Integrated Pest Management (IPM) is a tool that has become an environmentally friendly and climate-resilient strategy to improve productivity and profitability, and decrease the reliance on pesticides. The current study was carried out in Dharwad district for the year 2024-25 to analyze the economics of IPM for Bengal gram cultivation. A multi-stage random sampling method was used to select 120 farmers from which 60 farmers used IPM and 60 farmers did not use IPM. A pre-tested interview schedule was developed and used for primary data collection, and descriptive statistics, cost and returns analysis, Cobb-Douglas production function and partial budget analysis were used to analyze primary data. Results showed that the level of education of the IPM farmers was relatively higher than that of the non-IPM farmers, and they also had more contact with extension services. The gross returns and net returns harvested by the IPM farmers were ₹ 88,800/ha and ₹ 35,350/ha, respectively, much higher than the non-IPM farmers. Also the benefit cost ratio in IPM farms (1.66) was better than the non-IPM farms (1.37) which proves that IPM technology is more economic. The adoption analysis revealed that the main IPM practices adopted by farmers were deep summer ploughing, seed treatment using bio-agents, neem based botanical spray and pheromone trap. The resource use efficiency analysis revealed that there was an efficient allocation of labour, seed, fertilizer and plant protection inputs in the IPM farms. Partial budget analysis showed that adoption of IPM resulted in additional net return of ₹ 15,030/ha and marginal benefit cost ratio of 4.32. The study resulted that IPM is an economically viable and environmentally friendly tactic for bengalgram production in dryland agriculture, which is climate resilient.

Keywords: Climate-resilient agriculture, Integrated Pest Management, Resource-use efficiency Partial budget analysis, Dryland farming systems

Agricultural sustainability, food security, and rural livelihoods are among the significant challenges being faced by the world due to climate change, especially in semi-arid and dryland areas (Sagar and Harun, 2020; Maitra *et al.* 2025). The changing climate has posed a serious challenge to pulse production

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systems in India due to the rise in temperature, irregular rainfall, and frequent periods of drought, which are likely to impact productivity and farm profitability (Sairam *et al.* 2023; Mukesh *et al.* 2024; Maitra *et al.* 2026). This has made climate-resilient agricultural technologies that boost productivity and at the same time reduce the use of natural resources especially significant in the context of sustainable agricultural systems (Mwadalu *et al.* 2022; Santosh *et al.* 2024; Sairam *et al.* 2025). IPM is also considered one of the most effective climate-smart and environmentally-friendly methods that plays a pivotal role in sustainable agriculture by reducing the use of unnecessary pesticides, the pollution of the environment and ecological imbalance (Krishna *et al.* 2024; Rishitha *et al.* 2025). Adoption of IPM also contributes to several Sustainable Development Goals (SDGs) of the UN, such as SDG 2 (Zero Hunger), SDG 12 (Responsible Consumption and Production), SDG 13 (Climate Action) and SDG 15 (Life on Land) through sustainable crop production and resource conservation (Manasa *et al.* 2021; Maitra *et al.* 2024; Ray *et al.* 2025).

Bengal gram (*Cicer arietinum* L.), popularly called chickpea, is one of the most important pulse crops grown in India and has a significant role in providing nutritional security, improving soil fertility and earning livelihood to small and marginal farmers. India is the world's largest producer and consumer of Bengal gram and is a major producer in the world of pulses. The Bengal gram is also a significant dryland crop cultivated in rainfed condition in northern dry areas of Karnataka where it forms an integral part of the dryland farming system (Sarkar *et al.* 2000; Umesh *et al.* 2023). Insect pest infestation, however, has a significant impact on Bengal gram productivity, especially pod borer (*Helicoverpa armigera*), cutworms and aphids, leading to significant yield losses and dependence on chemical pesticides.

Extensive and indiscriminate chemical pesticide use in pulse production has led to several economic, environmental, and ecological issues such as pest resistance, resurgence of secondary pests, soil and water pollution, and risks to farmers and consumers' health (Muhie, 2022). Integrated pest management (IPM) is now a sustainable pest management method which combines biological, cultural, mechanical and need-based chemical techniques. IPM measures like

seed treatment with bio-agents, pheromone trap, use of neem-based botanical sprays and crop rotation and use of resistant varieties and need-based pesticide application have demonstrated good potential in the reduction of pesticide use and enhancement of crop productivity and farm profitability (Zaman *et al.* 2017; Hashim *et al.* 2026).

The economic and ecological advantages of IPM adoption in various crops, such as cost reduction of pesticides, better utilization of resources, and higher net profits have been reported in a few study areas (Kumar *et al.* 2022, Sharma *et al.* 2026). Awareness and promotion of IPM technologies by agricultural extension agencies and Krishi Vigyan Kendras (KVKs) have been enhanced, but the adoption of IPM practices among the Bengal gram farmers is still irregular distributed in various regions based on the socio-economic condition, awareness, technical knowledge, and input availability (Kumar *et al.* 2025). Furthermore, there is lack of studies on comparative economics and resource-use efficiency of IPM and non-IPM Bengal gram cultivation in the dryland of Northern Karnataka at the location. Previous research primarily concerned with technology dissemination and adoption behaviour, economic evaluation studies including cost and returns analysis, partial budgeting and production efficiency analysis are still scarce.

Therefore, the economic feasibility and resource-use efficiency of the IPM practices in Bengal gram cultivation in Dharwad district was carried out in the present study to fill this gap in research. The specific objectives of the study were: (i) to compare socio-economic characteristics, cost of cultivation and returns of the IPM and non-IPM bengalgram farmers, and (ii) to analyze the adoption pattern, resource-use efficiency and partial budget implication of IPM practices in the cultivation of Bengal gram system.

MATERIALS AND METHODS

The present investigation was carried out by ICAR-KVK, Dharwad for Dharwad district of Karnataka, India during 2024–25 for the study of economics of IPM in Bengal gram. The district of Dharwad falls under the Northern Transitional Zone of Karnataka which has semi-arid climate with medium black soils suitable for pulse cultivation. Bengalgram (*Cicer arietinum* L.) is one of the important rabi pulse crops

which is grown in the district under rainfed and limited irrigated condition. The region receives an average annual rainfall of 750-850 mm mostly from southwest monsoon and is susceptible to insect pests and climatic variations to grow pulse. The farmers in the area have started to use more modern pest control methods in recent years, as they become more aware of the need to protect the environment, the resistance of pests to these products, and the higher costs of farming. Fig. 1 shows the location of the study area.

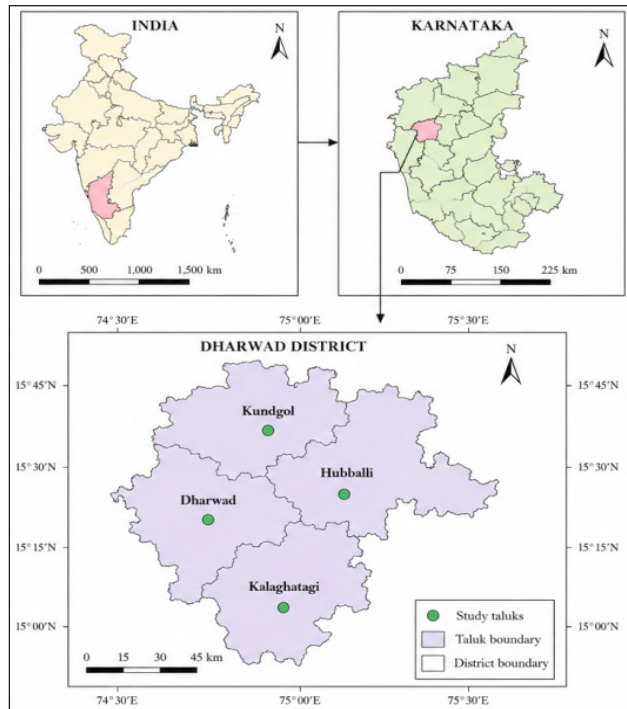


Fig. 1: Location map of the study area showing Dharwad district and selected taluks in Karnataka, India

Multistage random sampling technique has been adopted for the selection of the respondents. The area of Bengal gram crop in the district of Dharwad is large and there is a high level of interest in implementing IPM which is being promoted by the Department of Agriculture, Krishi Vigyan Kendras (KVKs) and agricultural extension agencies so Dharwad district was purposively selected for the first stage. The second stage involved selecting four major taluks of Bengal gram-producing area, namely, Dharwad, Hubballi, Kalaghatagi and Kundgol. Based on the discussions with the agricultural officers and extension personnel, three villages in each taluk with a significant proportion of Bengal gram cultivation were identified. In the last stage, 120 Bengal gram

farmers were selected with simple random sampling technique, 60 farmers were IPM adopters and 60 farmers were non-IPM farmers. The farmers who practiced at least four recommended IPM practices (seed treatment with bio-agents, pheromone traps, neem based botanical sprays, crop rotation, deep ploughing in the summer and need based pesticide application) were regarded as IPM adopters.

Both primary and secondary data were used in the study. Personal interview method with a pre tested and structured interview schedule was used to gather primary data from the selected respondents. The socio-economic characteristics, farm size, input utilization, pest management practices, cost of cultivation, yield, return and constraints on IPM adoption from the respondents were collected. Secondary data on area, production, productivity of Bengal gram and recommended IPM practices was gathered from the Department of Agriculture, Government of Karnataka, Directorate of Economics and Statistics, published research journals, books and the FAO reports.

The collected data was tabulated and analyzed in accordance with the objectives of the study using the appropriate statistical and economic instruments. The socio-economic attributes of the IPM and non-IPM Bengal gram growers were compared using descriptive statistical measures which include means, percentages, standard deviation and independent sample t-test. The influence of the variables on the adoption of the IPM practices was analyzed through the factors of age, education, family size, land holding, annual income, number of years farming experience and extension contacts. The t-test statistic used in the study was:

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\left(\frac{S_1^2}{n_1}\right) + \left(\frac{S_2^2}{n_2}\right)}}$$

where, $\bar{X}_1$ and $\bar{X}_2$ represent the means of IPM and non-IPM farmers, respectively; S_1^2 and S_2^2 denote variances; and n_1 and n_2 indicate sample sizes.

The economic analysis of Bengal gram production under IPM and non-IPM system was carried out based on the standardized concept of cost. Total cost of cultivation was split into variable cost and fixed cost. The variable costs consist of that on human labour, machine labour, seed, fertilizers and manures, plant protection chemicals, bio-control

agents, irrigation charges and interest on working capital while the fixed costs include the rental value of land, depreciation on implements, land revenue and interest on fixed capital. Gross returns were obtained by multiplying yield with prevailing prices and net returns were estimated by subtracting total cultivation cost from gross returns. The ratio of gross returns to total cost of cultivation was calculated to obtain the benefit-cost ratio.

Percentage analysis was used to analyze the adoption level of the various components of IPM. Major IPM practices studied comprised deep summer ploughing, treatment of seed with bio-agents, neem-based botanical sprays, pheromone trapping, bird perching, intercropping, crop rotation, need-based pesticide uses and resistant varieties. Percentage of adopters was determined by dividing the number of adopters by the number of respondents and multiplying by 100.

The efficiency of resource utilization of Bengal gram cultivation was calculated separately in Bengal gram cultivation of IPM and non-IPM farms by Cobb-Douglas production function model. The functional form of the model used was:

$$Y = aX_1^{b_1} X_2^{b_2} X_3^{b_3} X_4^{b_4} X_5^{b_5} e^u$$

The logarithmic form of the equation estimated was:

$$\log Y = \log a + b_1 \log X_1 + b_2 \log X_2 + b_3 \log X_3 + b_4 \log X_4 + b_5 \log X_5 + u$$

where, Y denotes gross returns (₹/ha); X_1 , X_2 , X_3 , X_4 and X_5 represent expenditure on human labour, seed, fertilizers, plant protection chemicals, and farmyard manure, respectively; a is the intercept; b_i are regression coefficients; and u is the random error term. The regression coefficients were estimated using Ordinary Least Squares (OLS) method and the sum of coefficients was used to determine returns to scale (Fatih, 2025).

The economic benefits due to IPM practices in Bengal gram cultivation were estimated by using the partial budget analysis. Additional returns, cost savings, further costs and net gains from implementing IPM were also analysed. Net economic gain due to IPM adoption was estimated using the following expression:

$$\text{Net Gain} = (\text{Added Returns} + \text{Reduced Costs}) - (\text{Added Costs} + \text{Reduced Returns})$$

Marginal Benefit-Cost Ratio (MBCR) was computed as:

$$\text{MBCR} = \text{Additional Benefits} / \text{Additional Costs}$$

Economic feasibility and profitability of IPM adoption were suggested by an MBCR value greater than one. Data collected were analysed using the MS Excel and SPSS statistical software packages.

RESULTS AND DISCUSSION

The findings of the present investigation about the economic analysis of Integrated Pest Management (IPM) in Bengal gram cultivation were analyzed and interpreted with the help of appropriate statistical and economic tools.

Table 1 shows that the IPM farmers were younger, better educated, and more contact with the extension and more organization participated than non-IPM farmers. The mean years of schooling among IPM farmers (8.40 years) was significantly more than the mean years of schooling of non-IPM farmers (5.30 years), which shows that education is a critical factor affecting the implementation of improved pest management practices (Kumar *et al.* 2023; Chouhan *et al.* 2023). Likewise, the income received from farm and farmer organization participation was found to be higher in the case of IPM adopters, indicating good access to information, institutional and technical support (BIRTHAL *et al.* 2022). The results suggest that socio-economic factors have great effect on adoption of sustainable agricultural technologies. Previous research has also shown that level of education, social participation and awareness have a significant impact on farmers' willingness to adopt eco-friendly crop protection technologies (Reddy *et al.* 2022). The above agricultural extension studies were also found to support the findings that farmers with less experience and education were more inclined towards IPM technologies as they lack technical knowledge and access to agricultural extension services and their risk-bearing capacity was also low.

Table 1: Socio-economic characteristics of IPM and Non-IPM Bengal gram growers in Dharwad district

Particulars	IPM Farmers (n=60)	Non-IPM Farmers (n=60)	Overall Mean	t-value
Average age (years)	43.20	47.10	45.15	2.18*
Education (years of schooling)	8.40	5.30	6.85	3.26**
Family size (No.)	5.80	5.40	5.60	0.92NS
Operational land holding (ha)	3.12	3.45	3.29	1.08NS
Area under bengalgram (ha)	1.86	1.72	1.79	0.84NS
Farming experience (years)	18.40	21.70	20.05	1.96*
Extension contact score	7.85	4.62	6.24	4.31**
Membership in farmer organizations (%)	68.33	41.67	55.00	2.87**
Annual farm income (₹/year)	2,48,500	2,06,700	2,27,600	2.44*

Note: NS = Non-significant; * Significant at 5% level; ** Significant at 1% level.

The cost and returns analysis (table 2) showed that the net and gross returns of the IPM farmers were better (₹ 35,350/ha and ₹ 88,800/ha respectively) than that of the non-IPM farmers, although the former had slightly higher cultivation cost. Cost for chemical pesticides was significantly lower by the IPM farmers while the cost of bio-control agents and eco-friendly elements of pest management were relatively higher. The output-input ratio was also better in IPM farms (1.66) as compared to non-IPM farms (1.37) which is again showing higher economic efficiency of the IPM technology in production of Bengal gram. The enhanced profitability could be explained in terms of decreased pesticide costs and incidence of pests as well as improved health of the crops under integrated management practices (Singh *et al.* 2020). The same was observed by recent studies on pulse and vegetable crops that found IPM adopters obtained higher farm income and reduced dependence on synthetic pesticides (Jat *et al.* 2024). This is also said to enhance the efficiency of resource use and long-term soil and ecosystem health in dryland farming systems (Jat *et al.* 2020). Moreover,

the use of integrated pest management methods also plays a crucial role in lowering the likelihood of production hazards as well as the environmental contamination from indiscriminate pesticide use (Reddy, 2018).

Table 2: Cost and returns structure of IPM and Non-IPM Bengal gram cultivation in Dharwad district (₹/ha)

Particulars	IPM Farmers	Non-IPM Farmers
Human labour	14,250	13,480
Bullock and machine labour	6,820	6,540
Seed	4,950	4,720
Farmyard manure	3,600	2,850
Fertilizers	5,420	5,860
Plant protection chemicals	3,180	6,540
Bio-control agents and traps	2,450	620
Interest on working capital	1,860	1,940
Miscellaneous expenses	1,270	1,180
Total variable cost	43,800	43,730
Fixed cost	9,650	9,420
Total cost of cultivation	53,450	53,150
Yield (q/ha)	14.80	12.10
Gross returns (₹/ha)	88,800	72,600
Net returns (₹/ha)	35,350	19,450
Output-input ratio	1.66	1.37

Note: Gross returns calculated at prevailing market price of ₹ 6,000/q.

The adoption pattern (Table 3) revealed that Bengal gram farmers are most adopting IPM practices such as deep summer ploughing, seed treatment with bio-agents, neem based botanical sprays and need based application of pesticide. A higher percentage of IPM farmers (70.3 per cent) showed awareness of the use of eco-friendly methods like pheromone traps and resistant varieties, thereby promoting sustainable pest management (Sharma *et al.* 2017). But comparatively less adoption was seen with intercropping and mechanical destruction of larvae, which may be attributed to labor constraints and technical guidance. All of the results showed that farmers preferred the practices that are economically viable, locally available and easy to be used under rainfed conditions. Ali and Rose *et al.* (2021) made similar observations regarding the adoption of cultural and botanical pest control practices over

the labour-intensive ones. Recent research about the pulse ecosystems also suggested that the availability of inputs, technical knowledge and extension services are important factors affecting adoption intensity of IPM technologies (Mishra *et al.* 2021). Furthermore, climate-smart sustainable pest management practices using neem formulations, pheromone traps, bioagents, etc. have been gaining popularity as a sustainable alternative in pulse-based cropping system.

Table 3: Adoption pattern of different IPM components in Bengal gram cultivation in Dharwad district

IPM Components	Number of Farmers Adopting	Adoption (%)
Deep summer ploughing	52	86.67
Seed treatment with bio-agents	48	80.00
Use of pheromone traps	44	73.33
Bird perches installation	41	68.33
Neem-based botanical sprays	46	76.67
Mechanical destruction of larvae	38	63.33
Intercropping with sorghum/ coriander	35	58.33
Need-based pesticide application	50	83.33
Use of resistant varieties	42	70.00
Crop rotation practices	39	65.00

Table 4, the resource use efficiency analysis revealed that human labour, seed, farmyard manure and fertilizers were significant contributors to Bengal gram production within IPM farms while plant protection chemicals were significant in non-IPM farms when Cobb–Douglas production function was used. The coefficient of determination (R^2) was higher in the IPM farms (0.82), representing a good explanation of the output variability with efficient use of the resources. The returns to scale were closer to unity under IPM conditions which indicated balanced and economically rational utilization of production factors. The higher value of the regression coefficient of the pesticides in the non-IPM farms meant more reliance on chemical control measures. The findings indicated that can be concluded that the IPM farmers were more productive in using integrated and efficient use

of resources than in using an excessive dose of chemicals. Zhang *et al.* (2022) reported similar results that IPM adopters had higher allocative efficiency and higher marginal productivity of inputs in a pulse production system. Agricultural economics studies have also found that IPM production systems improve labour productivity, nutrient-use efficiency and sustainability of the farms, and reduce environmental risks (Giller *et al.* 2015). Additionally, IPM has been identified as one of the key measures for enhancing resource conservation and climate resilient dryland agriculture.

Table 4: Resource use efficiency in Bengal gram production under IPM and Non-IPM farms in Dharwad district

Variables	Regression Coefficient (IPM)	Regression Coefficient (Non-IPM)
Human labour (X_1)	0.312**	0.284*
Seed (X_2)	0.226*	0.194*
Fertilizers (X_3)	0.184*	0.267**
Plant protection chemicals (X_4)	0.092NS	0.341**
Farmyard manure (X_5)	0.156*	0.088NS
Irrigation and moisture conservation (X_6)	0.118NS	0.074NS
Constant	1.842	1.526
R^2	0.82	0.76
Returns to scale	1.088	1.248

Note: Significant at 5% level; ** Significant at 1% level; NS = Non-significant; The regression coefficients were estimated using Cobb–Douglas production function.

The partial budget analysis given in Table 5 clearly showed that farmers' economic benefit significantly increased when they adopted IPM practices in Bengal gram cultivation. The extra returns from using higher yielding varieties and the savings on pesticide costs (₹ 19,560/ha) were higher than the extra cost for the pheromone traps, bio-control agents, botanical formulations and labour requirement (₹ 4,530/ha). The net gain from IPM adoption was therefore estimated at ₹ 15,030/ha and the marginal benefit-cost ratio (MBCR) was estimated at 4.32, which are economically feasible and profitable in dryland situation, and proving IPM technologies successful. Technical benefits of the higher returns due to

IPM, include lower crop losses, better pest control, and better use of environmentally-friendly pest management inputs. The same has been observed in the recent pulse crop studies where farmers' profitability, pesticide dependency and farmer's income sustainability were tied to significant improvement when he implemented IPM (Zhou *et al.* 2024). Economics studies of recent years in pulse production systems also showed that the use of improved technologies for pest and crop management had significantly higher net returns and benefit cost ratios than conventional farming (Verma *et al.* 2024). In addition, IPM practices are gaining momentum as cost-effective and sustainable ways to reduce environmental and health risks and lower the reliance on pesticides without compromising quality in pulse production (Awasthi *et al.* 2006).

Table 5: Partial budget analysis of IPM adoption in Bengal gram cultivation (₹/ha)

Particulars	Amount (₹/ha)
Added returns	
Increase in yield due to IPM	16,200
Savings in pesticide expenditure	3,360
Total added benefits	19,560
Added costs	
Cost of pheromone traps	1,250
Cost of bio-control agents	980
Additional labour for monitoring	1,540
Botanical pesticide preparation	760
Total added costs	4,530
Net gain due to IPM adoption	15,030
Marginal Benefit-Cost Ratio (MBCR)	4.32

CONCLUSION

The present study showed clearly that the adoption of Integrated Pest Management (IPM) practices in Bengal gram cultivation significantly improved the economic performance and resource-use efficiency of the farmers in Dharwad district. The results showed that the IPM farmers were relatively better educated, had more contact with extension, and had higher net returns and benefit-cost ratio than farmers who were not IPM. Lower purchase of chemical pesticides and smart use of the ecological components of pest management helped to improve profitability for IPM cultivation. It was also revealed from the study

that IPM farmers had obtained greater productivity by proper use of inputs and lesser use of synthetic pesticides. The analysis of adoption revealed that the farmers adopting IPM have widely adopted deep summer ploughing, bio-agents treatment, need based pesticide application, botanical sprays using neem and pheromone traps. Partial budget analysis also showed the economic viability of IPM technology in terms of higher additional return and marginal benefit cost ratio. The findings highlight the positive effects of IPM on farm profitability, as well as its role in promoting environmental sustainability by minimizing the use of chemicals, maintaining ecological equilibrium, and preserving natural resources. Therefore, IPM can be used as an effective climate resilient measure for sustainable pulse production under the dryland ecosystems.

It is important to intensify extension service, farmer training programmes and timely availability of bio-control inputs to promote the uptake of IPM technologies among the Bengal gram growers, the study says. Educating the adoption of sustainable pest management (SPM) can be a key component in sustainable agricultural development and contribute to meeting Sustainable Development Goals (SDGs) concerning food security, responsible consumption, climate action and ecosystem conservation. Thus, policy interventions on capacity building, institutional support and climate smart agriculture are needed to boost the productivity, profitability and sustainability of Bengal gram production systems in semi-arid regions.

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