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Economic viability and environmental benefits of IPM adoption by chilli farmers of Karnataka: A success case study

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Abstract
The study was conducted in Haveri district, Karnataka, during 2024-25 to assess the impact of Integrated Pest Management (IPM) compared to Non-IPM practices in chilli cultivation. Utilizing a survey-based approach, data were collected from farmers participating in demonstration projects implementing both IPM and Non-IPM techniques. The results indicated that 100 per cent of respondents gained knowledge about IPM techniques upon project completion. Additionally, 52 per cent of respondents identified pest infestations, particularly thrips and mites, as key factors reducing chilli yields. Only 28% of respondents demonstrated awareness of the economic threshold level (ETL), while the remainder lacked familiarity with the concept. The study also highlighted that all respondents practiced hand washing after chemical applications, and 72 per cent reported using protective coverings for their face and body during spraying. Overall, the findings underscore the benefits of IPM adoption, including improved yield quality, sustainable pest control, and enhanced soil and environmental health. This research supports the role of IPM in promoting sustainable agricultural practices among chilli farmers. The study further demonstrated that chilli cultivation using the IPM method is economically viable, yielding a favourable Benefit-Cost (B: C) ratio and higher net returns compared to Non-IPM practices.

Keywords: IPM, survey, chilli, ETL, sustainable, demonstration, pest

Introduction
Chilli (*Capsicum annuum* L.) is one of the most important commercial vegetable-cum-spice crops cultivated across temperate, tropical, and subtropical regions of the world. With over 400 varieties globally, it is commonly referred to as hot pepper, cayenne pepper, sweet pepper, or bell pepper. Belonging to the family *Solanaceae*, it holds a significant position in global agriculture and cuisine.

Among the various chilli varieties, the Byadagi chilli, predominantly grown in Karnataka, is renowned for its distinct characteristics. There are two main types: *Byadagi Dabbi* and *Byadagi Kaddi*. The *Byadagi Dabbi* variety, small and plump, is particularly prized for its vibrant red color, unique flavor, and mild heat. Named after the town of Byadagi in Haveri district, this chilli variety boasts the second-largest turnover among Indian chilli varieties. The deep red pigment and oleoresin extracted from Byadagi chilli are widely used in the cosmetics industry, including nail polish and lipsticks, as well as in South Indian culinary preparations. The variety was accorded a Geographical Indication (GI) tag (129) in February 2011. Its oleoresin is exported to countries like the USA, Japan, and Europe, underscoring its international significance (Anonymous, 2015) [1].

India is the largest producer, consumer, and exporter of chillies globally, with cultivation covering 774.9 thousand hectares and an annual production of 1,492.10 thousand tonnes. Andhra Pradesh is the leading chilli-producing state, followed by Maharashtra, Karnataka, Odisha, and Madhya Pradesh. Approximately 80% of India's chilli production is consumed domestically, with only 15-20% allocated for export. Apart from culinary uses, chillies are utilized in various industries.

Capsaicin extracted from ripe fruits is used in pharmaceuticals for treating heart conditions, and chilli extracts are incorporated in beverages, cosmetics, and medicinal balms. The oleoresin extracted from chillies is favoured in the food industry for its colour and flavour distribution advantages over traditional chilli powders. Additionally, chillies exhibit antioxidant, anti-mutagenic, hypocholesterolemic, and immunosuppressive properties.

Despite its importance, chilli cultivation faces numerous challenges, including pest infestations by thrips, whiteflies, mites, and fruit borers, as well as diseases like wilt, fruit rot, and leaf spots. Climatic changes have further impacted chilli cultivation in regions like Haveri, Karnataka, where a 37.31% annual reduction in cultivation area has been reported over the past decade (Ashoka *et al*., 2021) [3]. To meet the growing demand for chillies, there is a need to expand the cultivation area and enhance productivity per unit area. Adopting advanced techniques such as Integrated Pest Management (IPM) offers a sustainable solution. IPM minimizes pest damage while promoting ecological balance and ensuring higher yields and quality.

This study examines the socio-economic and agronomic impact of adopting IPM technology in chilli cultivation. Objectives include assessing the percentage adoption of IPM, understanding the status of farmers before and after IPM adoption, and evaluating the benefits of this technology in improving chilli productivity and sustainability.

Methodology

The Horticulture Research and Extension Centre, Devihosur, Haveri, in collaboration with the National Centre for Integrated Pest Management, New Delhi, implemented a project titled "Synthesis, Validation, and Promotion of IPM Technology in Chilli" in Haveri district from 2021 to 2022. The study focused on four selected villages: Devihosur, Hosalli, Aladakatti, and Kabbur. The project aimed to provide knowledge and technical expertise on Integrated Pest Management (IPM) practices and supplied IPM components such as pesticides, seeds, traps, and vermicompost to farmers.

Ten progressive farmers, each owning at least 2 acres of land, were selected for the project. These farmers demonstrated both IPM and Non-IPM methods on one acre each. The project spanned three years, during which farmers gained hands-on experience in the comparative application of these methods.

The impact assessment was conducted in 2024, following the completion of the demonstration project. Using a purposive sampling technique, the same farmers involved in the initial project were surveyed between May and July 2024. Data collection utilized pretested schedules to capture socio-economic information, including age, education, family type, cost reductions, incurred costs, and other relevant parameters. The data from 25 farmers, who were trained and engaged during the project, were analyzed using descriptive statistical tools such as totals and percentages to interpret the findings.

Results and Discussion

Socio Economic Analysis

The study highlighted (Table 1) that all the respondents (100%) possessed knowledge about Integrated Pest Management (IPM), aligning with findings by Patel and Sanwal (2015) [7], who noted that most farmers are aware of IPM practices and their advantages. A common agricultural practice among respondents was the use of raised seedbeds for cultivating seedlings.

Interaction with Agricultural Institutions

The frequency of farmers visiting Krishi Vigyan Kendras (KVKs) or related institutions was low, with only 4% visiting regularly, 16 per cent occasionally, and 80 per cent rarely. These results align with the observations of Rao and Rao (2010) [11], who reported that most Indian farmers rely on dealers (51%) and extension officials (22%) for plant protection advice. The limited visits may be due to factors like the distance of institutions from villages or inadequate transport facilities.

Adoption of IPM Practices and Pest Management

Farmers acknowledged the effectiveness of discussions with experts in reducing the number of pesticide sprays. Regarding technical needs, all respondents prioritized pesticide information. Additionally, 100% of the farmers identified mites as a major cause of yield reduction, while 52 per cent highlighted the role of thrips, 44 per cent fruit borers, and 20 per cent whiteflies.

After three years of IPM demonstrations, 76 per cent of respondents confirmed a significant reduction in pest and disease infestations. However, only 12 per cent of the farmers were familiar with the concept of Economic Threshold Levels (ETL), while 60 per cent lacked this knowledge, indicating a need for further training.

IPM Acceptance and Benefits

All respondents considered IPM a convenient, useful, and economical approach to sustainable plant protection. While 100% integrated chemical methods with botanicals and bioagents, only 36 per cent showed higher interest in using bio-agents. Farmers expressed a strong willingness to continue using IPM practices in the future.

Predators such as spiders and praying mantises were observed by all respondents, while 76 per cent also reported finding coccinellids in their fields. Awareness of using pheromones and sticky traps was universal (100%), consistent with Mahalaxmi and Tulasiram (2018) [13], who found that 65 per cent of farmers were knowledgeable about these methods.

Challenges in Pesticide Usage

The study revealed that 60 per cent of respondents were unaware of banned pesticides and the risks of overuse, highlighting the need for enhanced training programs. Additionally, 80 per cent of respondents relied on pesticide dealers for advice, which often led to exploitation. Nevertheless, all farmers were aware of the environmental and health hazards posed by pesticide contamination, corroborating findings by Tamizheniyan (2001) [12].

Adoption of Safe Practices

While all respondents reported washing their hands after spraying, only 72 per cent covered their face and body during spraying. The remaining 28% failed to adopt these protective measures, underscoring the need for awareness campaigns.

Cost and Spray Frequency

The study found that 76 per cent of respondents performed 5-10 sprays per crop cycle, 20 per cent conducted 10-15 sprays, and 4 per cent carried out fewer than five sprays. The majority (84%) spent ₹10,000-20,000 per acre on pest management. A significant cost reduction was noted among respondents, with 44 per cent saving ₹25,000-50,000, 4 per cent saving ₹10,000-20,000, and 52% saving ₹5,000-10,000 due to reduced pesticide use. These results align with Sadique *et al*. (2018), who reported cost savings and reduced pesticide applications in IPM-adopted fields.

Yield and Economic Gains

The impact of IPM on yield was evident, with 20 per cent of respondents achieving 10-15 quintals/ha, 72 per cent harvesting 5-10 quintals/ha, and 8 per cent producing 1-5 quintals/ha. This indicates that farmers who properly adopted IPM practices obtained higher yields and economic returns, while those who did not adopt the practices experienced comparatively lower returns.

Age Distribution of IPM Beneficiary Farmers

The age distribution (Table 2) of IPM beneficiary farmers revealed that 44 per cent were in the 20-30 age group, 32 per cent belonged to the 30-40 age group, and 12 per cent fell within the 40-50 age group. Only 12% of respondents were above 50 years of age. These results are in line with Patel and Sanwal (2015) [7], who indicated that the younger demographic is more likely to strictly follow IPM practices.

Education Level of IPM Beneficiary Farmers

Regarding educational background (Table 3), 48 per cent of the respondents had completed education up to the 7th to 10th grade, 32 per cent had finished 10th to 12th grade, 12 per cent were illiterate, and 8 per cent had completed a degree. This demonstrates an increasing awareness about education among the farmers.

Landholding of IPM Beneficiary Farmers

The study revealed (Table 4) that 56 per cent of the respondents had medium-sized land holdings, 24 per cent owned 1-2 ha, and 20 per cent had larger land holdings. Most of the IPM beneficiaries were found to possess marginal land holdings.

Economic Status of IPM Beneficiary Farmers

In terms of economic status (Table 5), 56 per cent of respondents had a medium economic status, 28 per cent had a high economic status, and 24 per cent had a low economic status. These findings align with Adhikari (2007) [9] and Chouhan (2007) [10], who reported similar economic distributions among farmers.

Innovativeness of IPM Beneficiary Farmers

Innovativeness among the farmers was assessed, with 24 per cent being highly innovative, 44 per cent exhibiting medium innovation, and 32 per cent classified as low innovative (Table 6). In total, 68 per cent of respondents demonstrated some level of innovation. These findings are corroborated by Verma *et al*. (2018) [8], who also observed a high degree of innovation among IPM adopters.

Economics chilli cultivation in IPM and Non IPM fields

The comparison between Integrated Pest Management (IPM) and Non-IPM fields shows significant differences in economic and agronomic parameters (Table 7). IPM fields recorded an average of 6.4 sprays with 12.8 chemical applications, while Non-IPM fields had 8.4 sprays with 22.4 applications. This highlights the efficiency of IPM in reducing chemical inputs, supporting sustainable farming practices. The cost of pesticides and growth boosters in IPM fields was ₹7,468, significantly lower than ₹13,836 in Non-IPM fields. This reduction of ₹6,368 reflects better resource utilization in IPM, even though an additional ₹3,995 was incurred for IPM-specific inputs. Despite this, the total cultivation cost in IPM fields was ₹78,169, slightly lower than ₹79,092 in Non-IPM fields. IPM fields achieved a higher mean yield of 6.69 tonnes per acre compared to 6.4 tonnes in Non-IPM fields. This improved productivity demonstrates the effectiveness of IPM strategies in maintaining crop health and maximizing output. IPM fields generated a gross return of ₹1,52,750 per acre, exceeding the ₹1,47,800 from Non-IPM fields. This translated into a superior Benefit-Cost (B:C) ratio of 1:1.95 for IPM compared to 1:1.86 for Non-IPM, emphasizing the higher profitability of IPM practices. The study underscores the multifaceted benefits of IPM. By reducing chemical dependency, IPM not only lowers input costs but also mitigates environmental risks. The slight yield advantage further solidifies IPM as a practical approach to enhancing agricultural productivity. From an economic perspective, the lower expenditure on pesticides and labour, coupled with higher gross returns, makes IPM a financially sound option. The negligible difference in cultivation costs between the two systems suggests that adopting IPM does not impose additional financial burdens on farmers. Instead, the higher B:C ratio in IPM fields indicates better resource efficiency and profitability.

Cost and returns of chilli in IPM and Non - IPM plots

The economic analysis of Integrated Pest Management (IPM) and Non-IPM plots in chilli cultivation demonstrates (Table 8) clear differences in cost structure, returns, and profitability. The chilli yield per acre was slightly higher in IPM plots (6.69 tonnes) compared to Non-IPM plots (6.4 tonnes). This yield difference resulted in a corresponding increase in the total income per acre, which was ₹1, 52,750 for IPM and ₹1, 47,800 for Non-IPM plots. The enhanced yield in IPM reflects the effective pest management strategies contributing to better plant health and productivity. The total cost of cultivation for IPM plots was ₹78,169, slightly lower than ₹79,092 for Non-IPM plots. The protection cost in IPM plots was ₹11,463, which includes spray charges, pesticide costs, growth boosters, and ₹3,995 for IPM-specific inputs. In comparison, Non-IPM plots had a higher protection cost of ₹13,836, attributed to increased chemical usage. The efficient resource management in IPM practices led to a reduction in overall production and protection expenses. The net income per acre from IPM plots was ₹74,581, notably higher than the ₹68,708 generated from Non-IPM plots. This difference of ₹5,873 underscores the financial benefits of IPM practices, driven by lower input costs and higher yields.The B:C ratio for IPM plots was 1:1.95, higher than the 1:1.86 observed in Non-IPM plots. This superior ratio highlights the improved profitability and cost-effectiveness of IPM methods compared to traditional Non-IPM practices. The study clearly demonstrates the advantages of IPM in chilli cultivation. By integrating pest management strategies, farmers can achieve higher yields with reduced dependency on chemical inputs. The lower protection cost in IPM plots indicates better resource utilization and environmental sustainability. The improved net income and B:C ratio further emphasize the economic feasibility of IPM, offering farmers a viable and profitable alternative to conventional practices. Additionally, the reduced pesticide usage aligns with sustainable agricultural practices, ensuring long-term soil health and environmental safety.

Table 1: Socio Economic Impact Analysis, (n=25)

Sl. No.	Particulars	Frequency	Per cent
1.	**Knowledge about Integrated Pest Management**		
	Yes	25	100
	No	0	0
2.	Practice raised seedbed method		
	Yes	25	100
	No	0	0
3.	**Contact experts from KVK and nearby agri research centers**		
	Regularly	01	04
	Occasionally	04	16
	Rarely	20	80
	Never	0	0
4.	**Interaction with officials help in minimizing number of sprays**		
	Yes	25	100
	No	0	0
	Not reply	0	0
5.	**The major technical information you will get from experts**		
	Bio agents	13*	52
	Varieties	5*	20
	Pesticides	25*	100
	All	11*	44
6.	**Pest has played an important role in lowering yield**		
	Thrips	13*	52
	Whitefly	5*	20
	Mites	25*	100
	Fruit borer	11*	44
7.	**IPM strategy has played an important role in lowering the damage**		
	Yes	19	76
	No	6	24
8.	**Knowledge about Economic Threshold Level**		
	Yes	15	12
	No	3	60
	Some idea	7	28
9.	**Opinion of IPM is convenient, useful and economic**		
	Yes	25	100
	No	0	0
	No Idea	0	0
10.	**IPM components you follow in recent days**		
	Botanical	9*	36
	Bio agents	12*	48
	Chemical	25*	100
11.	**Opinion to continue to use IPM**		
	Yes	25	100
	No	0	0
12.	**The natural enemies you found in the field**		
	Spider	25*	100
	Coccinellids	19*	76
	Praying mantis	25*	100
14.	**Knowledge about how to use pheromone traps, yellow sticky traps, Trichoderma**		
	Yes	25	100
	No	0	0
15.	**Idea about banned pesticides and overuse of pesticides**		
	Yes	10	40
	No	15	60
16.	**Dependence on the advice of pesticide dealers rather than agricultural experts**		
	Yes	20	80
	No	5	20
17.	**Aware of contamination of air and water by pesticides and adverse effect on beneficial insects**		
	Yes	25	100
	No	0	0
18.	**Practice of washing your hands after spraying of pesticides**		
	Yes	25	100
	No	0	0
19.	**Practice of covering face with cloth or cover body or other means**		
	Yes	18	72
	No	0	0

	Sometimes	7	28
20	**Number of sprays (cocktail No.) given month wise after IPM knowledge**		
	> 5 sprays	1	4
	5-10 sprays	19	76
	10-15 sprays	5	20
	15-20 sprays	0	0
21	**The cost of treatment/acre for pesticide after getting IPM knowledge (in Rs.)**		
	5-10 thousand	1	4
	10-20 thousand	21	84
	25-50 thousand	3	12
	>50 thousand	0	0
22	**Cost is saved through reduced pesticide spray (in Rs.)**		
	5-10 thousand	13	52
	10-20 thousand	1	4
	25-50 thousand	11	44
	>50 thousand	0	0
23	**IPM knowledge is more important for more yield?**		
	1-5q	2	8
	5-10q	18	72
	10-15q	5	20

*Multiple Responses

Table 2: Age of IPM beneficiary farmer, (n=25)

Sl. No.	Age in Years	Frequency	Per cent
1	20-30	11	44
2	30-40	08	32
3	40-50	03	12
4	>50	03	12

Table 3: Education of IPM beneficiary farmer, (n=25)

Sl. No.	Categories	Frequency	Per cent
1	Illiterate	03	12
2	7th to 10th Class	12	48
3	10th to 12th Class	08	32
4	Degree	02	08

Table 4: Land holding of IPM beneficiary farmer, (n=25)

Sl. No.	Categories	Frequency	Per cent
1	Small (1-2ha)	06	24
2	Medium (2-10ha)	14	56
3	Large –(>10ha)	05	20

Table 5: Economic status of IPM beneficiary farmer, (n=25)

Sl. No.	Categories	Frequency	Percentage
1	Low	06	24
2	Medium	14	56
3	High	07	28

Table 6: Innovativeness of IPM beneficiary farmer, (n=25)

Sl. No.	Categories	Frequency	Percentage
1	Low	08	32
2	Medium	11	44
3	High	06	24

Table 7: Economics chilli cultivation in IPM and Non IPM fields

Parameters	IPM	Non IPM
Number of chemical sprays (chemicals)	6.4 (12.8)	8.4 (22.4)
IPM inputs (Rs.)	3,995	---
Cost of pesticides and growth boosters/ sprays including labour (Rs.)	7,468	13,836
Cost of cultivation (Rs.)	78,169	79,092
Mean total yield t/ha	1.67	1.66
Gross return (Rs.)	1,52,750	1,47,800
B: C ratio	1: 1.95	1: 1.86

Table 8: Cost and returns of chilli IPM and Non - IPM plots

Green chilli/ (t/acre)		Total Income (Rs/acre)		Cost of cultivation (Rs/acre)						Net Income (Rs/acre)		B:C ratio	
				Production cost		Protection cost (Rs)		Total Cost (Rs)					
IPM	Non IPM	IPM	Non IPM	IPM	Non IPM	IPM	Non IPM	IPM	Non IPM	IPM	Non IPM	IPM	Non IPM
6.69	6.4	1,52,750	1,47,800	68,506	67,956	11,463*	13,836%	78,169	79,092	74,5581	68,708	1: 1.95	1: 1.86

*---includes spray charges, pesticide cost, growth booster cost, IPM inputs (3,995-IPM inputs)

%--- includes spray charges, pesticide cost, growth booster cost

Conclusion

This study highlights the positive impact of Integrated Pest Management (IPM) on farming, showing that farmers benefit from lower production costs, reduced pesticide residues, and more sustainable yields. IPM improves farm productivity while ensuring environmental safety. Economically, IPM reduces input costs and increases returns. The total cost of cultivation in IPM fields (₹78,169) was slightly lower than in non-IPM fields (₹79,092), with IPM fields achieving higher yields (6.69 tonnes per acre) and gross returns (₹1,52,750 per acre) compared to non-IPM fields (6.4 tonnes and ₹1,47,800, respectively). Net income per acre was ₹74,581 in IPM fields, compared to ₹68,708 in non-IPM fields, a difference of ₹5,873. The Benefit-Cost (B:C) ratio for IPM (1:1.95) was also higher than non-IPM (1:1.86), showing greater profitability and resource efficiency. Despite the initial cost of IPM inputs, long-term savings on pesticides and higher yields make it a financially viable option. However, many farmers still lack adequate knowledge about IPM, which limits its adoption. To bridge this gap, investments in training, demonstrations, and extension services are crucial. These efforts will promote IPM's environmental and economic benefits, enabling farmers to adopt sustainable practices for better productivity.

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