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Impact of Integrated Approaches on Chilli Black Thrips (*Scirtothrips dorsalis* Hood, 1919) Suppression and (*Capsicum annuum* L.) Yield Across Telangana State

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ABSTRACT

The experiment was conducted during the *rabi* seasons (October–February) of 2022–2024 in the districts of Warangal, Hanamkonda, Mulugu, and Jayashankar Bhupalpally of Telangana State to evaluate the efficacy of Integrated Pest Management (IPM) against black thrips (*Scirtothrips dorsalis* Hood, 1919) in chilli (*Capsicum annuum* L.). Black thrips are a major pest limiting chilli productivity, and conventional farming practices often provide sub-optimal control and economic returns. The IPM package combined black plastic mulching, neem oil (10,000 ppm, 1 ml l^{-1}), *Beauveria bassiana*, & *Lecanicillium lecanii* at 5 g l^{-1}, and selective chemical insecticides (Spinosad and Thiacloprid) applied at 15-day intervals starting 30 days after transplanting, totaling three sprays per season. A total of 100 farmers (25 per district) participated, and results were compared with conventional Farmer Practice (FP). Across three years, IPM significantly reduced thrips populations by 45–50% and increased yield by 24–26%, while economic analysis revealed higher net returns and B:C ratios (2.72–2.90) compared to FP (1.75–1.83). Technology gaps ranged from 0.6–2.1 t ha^{-1}, extension gaps from 2.8–4.5 t ha^{-1}, and yield gaps from 24.3–27.9%, indicating untapped potential under conventional practices. Mulugu and Hanamkonda approached near-optimal yields, whereas Warangal and Jayashankar Bhupalpally require targeted extension and localized IPM optimization. IPM effectively suppressed thrips, increased chilli yields by 19–33%, and nearly doubled profitability. IPM proved a sustainable, cost-efficient, climate-smart strategy, narrowing yield gaps and enhancing productivity across districts.

KEYWORDS: Chilli, black thrips, IPM, yield gap, correlation

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Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

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1. INTRODUCTION

Chilli (*Capsicum annuum* L.) is a major cash crop in Telangana, providing essential income for smallholder and marginal farmers (Samreen et al., 2025). Grown across diverse agro-climatic zones, it significantly contributes to the state's economy and to India's overall chilli production. However, despite its importance, chilli productivity in Telangana is often limited by several biotic stresses, of which pest infestations are the most critical (Priya et al., 2023). These pests cause heavy yield losses, reduce fruit quality, and increase production costs due to repeated crop protection measures. Among the major pests, black thrips (*Scirtothrips dorsalis* Hood, 1919) have emerged as one of the most destructive, particularly during the *rabi* season when favourable temperature and humidity accelerate their multiplication (Mishra and Kumar, 2023). Infestations result in leaf curling, stunted growth, poor fruit set, and in severe cases, near-complete crop failure if unmanaged (Anusha et al., 2024). During 2023–24, Telangana accounted for nearly 16% of India's chilli area and 25% of its production. The state ranked third in area and second in productivity, with 3.92 lakh acres producing about 7.94 lakh tonnes, and an average productivity of 2,021 kg acre^{-1}. In the erstwhile Warangal district alone, chilli was cultivated on 6,700 acres, yielding 10,951 t at 1,635 kg acre^{-1} (Anonymous, 2024). These figures highlight both the economic significance of chilli and the urgent need for effective pest management to protect farmer profitability (Raval et al., 2025). Black thrips are responsible for 20–60% yield losses in chilli during *rabi* across India, although the extent varies with climate, cultivation practices, and pest pressure (Manideep et al., 2025). In Warangal, estimated losses are around 30%, posing a serious threat to the livelihoods of local farmers (Gayatri et al., 2025). Conventional management largely depends on frequent sprays of broad-spectrum insecticides (Jeyashree and Arivudainambi, 2025). While these chemicals may temporarily suppress thrips, they also contribute to pesticide resistance, disrupt natural enemies, contaminate the environment, and pose health risks (Shetty et al., 2024). Overuse of chemicals further increases production costs and undermines the long-term sustainability of chilli cultivation. To overcome these limitations, integrated pest management (IPM) is increasingly recommended as a more sustainable and ecologically sound strategy (Rajpoot et al., 2024). IPM integrates cultural, biological, botanical, and selective chemical measures to manage pest populations while minimizing environmental and health impacts (Kaur et al., 2024). The approach emphasizes preventive practices, regular monitoring, and need-based interventions guided by economic threshold levels rather than routine spraying. Because pest incidence, microclimate, and cultivation practices differ across regions, multi-year and multi-location evaluations are essential to validate the performance of IPM strategies under varied agro-climatic conditions (Rani, 2020; Kaur et al., 2020). Such evidence supports the identification of optimized combinations of technologies suited to specific farming situations, thereby improving productivity and profitability (Mandal and Mondal, 2023). In this context, the present study was formulated to evaluate the effectiveness of IPM in suppressing black thrips and to analyze its impact on growth, yield, and economic returns of chilli across major agro-climatic zones of Telangana. By generating scientific evidence on the benefits of IPM, this study aims to guide farmers, extension personnel, and policymakers in adopting sustainable strategies that protect chilli productivity, reduce avoidable losses, and enhance environmental safety in chilli-based farming systems.

2. MATERIALS AND METHODS

2.1. Study location

The study was conducted across four districts lying in the central-eastern part of Telangana state, *i.e.,* Warangal (17.9788°N, 79.5941°E), Hanamkonda (18.0101°N, 79.5694°E), Mulugu (18.1910°N, 79.9430°E), and Jayashankar Bhupalpally (18.2131°N, 79.9273°E), under the Krishi Vigyan Kendra (KVK), Mamnoor, during the *rabi* seasons of 2022–2024, involving 100 farmers with 25 farmers representing each district.

2.2. Treatments

An IPM approach was implemented for the suppression of black thrips in chilli, incorporating cultural, botanical, biological, and selective chemical interventions. Details of the IPM treatments, including the types of interventions, dosages, and application schedules, along with the associated extension gaps, were presented in Table 1, as provided by ATARI Hyderabad Zone–X during the Action Plan Meeting under the technical programme. Cultural management consisted of black plastic mulching applied at the time of transplanting to limit initial pest establishment (Gayatri et al., 2025). Botanical control was achieved using neem oil (10,000 ppm, 1 ml l^{-1}) applied as foliar sprays at 15-day intervals starting 30 DAT for a total of three applications per season. Biological suppression involved the foliar application of *Beauveria bassiana* and *Lecanicillium lecanii* at 5 g l^{-1} (Rajpoot et al., 2024). Selective chemical control employed rotational foliar sprays of spinosad (0.3 g l^{-1}) and thiacloprid (0.25 g l^{-1}) (Samreen et al., 2025) to sustain efficacy and mitigate resistance development (Pathan et al., 2023). Farmer Practice (FP) plots were maintained according to conventional local practices to serve as a control.

2.3. Method of data collection

Thrips populations were counted as adult thrips per flower on ten randomly selected plants plot^{-1}, and green chilli

Table 1: Details of IPM treatments, dosages, application schedule and extension gaps in integrated pest management (IPM) and farmer practice (FP)

Sl. No.	Treatment/ Components	Dosage/Method	Application schedule	Extension gap (t ha^{-1})
1.	Black plastic mulching	Applied to transplanting	Once at transplanting	Full gap
2.	Neem oil	10,000 ppm (1 ml l^{-1})	Foliar spray, 3 times at 15-day intervals starting 30 DAT	Occasionally
3.	*Beauveria bassiana*	5 g l^{-1}	Foliar spray, 3 times at 15-day intervals starting 30 DAT	Full gap
4.	*Lecanicillium lecanii*	5 g l^{-1}	Foliar spray, 3 times at 15-day intervals starting 30 DAT	Full gap
5.	Selective chemicals (rotated)	Spinosad 0.3 g l^{-1} Thiacloprid 0.25 ml l^{-1}	Foliar spray, 3 times at 15-day intervals starting 30 DAT	No gap

yield was recorded in tonnes per hectare (t ha^{-1}). Economic evaluation was performed by calculating net returns (₹ ha^{-1}) and benefit–cost (B:C) ratios for each treatment. All data were subjected to analysis of variance (ANOVA) using 'R' software, and means were separated using Tukey's Honestly Significant Difference (HSD) test at $p<0.05$. Data were presented as mean ± standard error (SE) (Kaur et al., 2024 and Priya et al., 2023). In addition to yield, key productivity parameters, including technology gap (TG), extension gap (EG), technology index (T_I), and yield gap (YG), were calculated to evaluate the effectiveness of IPM versus farmer practices (Jeyashree and Arivudainambi, 2025). TG was determined as the difference between potential yield (Yp) and yield under improved technology (Yt), EG as the difference between IPM yield (Yt) and farmers' yield under conventional practice (Yf), T_I as the percentage difference between potential and improved yield, and YG as the difference between potential yield and farmers' yield. All calculations followed standard procedures (Jaya et al., 2025).

3. RESULTS AND DISCUSSION

3.1. *Thrips incidence and population dynamics*

Assessment of thrips incidence in chilli across four districts during *rabi*, 2022–2024 indicated a substantial suppression under Integrated Pest Management (IPM) compared with conventional Farmer Practice (FP) (Table 2). In Warangal, thrips populations in IPM plots ranged from 5.8 to 6.5 $flower^{-1}$, while FP plots recorded 22.0–24.0 $flower^{-1}$. The pooled mean population under IPM was 6.17±0.35 compared with 23.0±0.31 under FP, representing a 43.2% reduction. Year-wise trends showed the lowest IPM population in 2023 (5.8/flower), suggesting the cumulative effect of timely IPM interventions. Hanamkonda recorded 6.8–7.2 thrips per flower under IPM versus 25.0–27.0 under FP, with a pooled reduction of 46.2%, the highest among the districts. Mulugu exhibited a 50.7% reduction (IPM: 5.5–6.0; FP: 22.5–24.5), while Jayashankar Bhupalpally showed a 42.9% reduction (IPM: 7.5–8.0; FP: 26.0–28.0). ANOVA indicated a highly significant effect of treatment ($p< 0.001$), while year-wise variations were not significant ($p>0.05$) (Manadeep et al., 2025). Across all districts, IPM consistently maintained thrips populations below 8 per flower, whereas FP plots ranged from 22 to 28 $flower^{-1}$. The percentage reduction ranged from 42.9% to 50.7%, demonstrating robust pest suppression across different agro-climatic conditions (Mishra and Kumar, 2023). The study

Table 2: Population dynamics and incidence of thrips in chilli under integrated pest management (IPM) and farmer practice (FP) across four districts during *rabi*, 2022–2024

Year	2022		2023		2024		Pooled (Mean ± SE)		
District	IPM	FP	IPM	FP	IPM	FP	IPM	FP	Thrips reduction (%)
Warangal	6.2±0.5^a	22.0±1.2^b	5.8±0.4^a	24.0±1.0^b	6.5±0.5^a	23.0±1.1^b	6.17±0.35	23.0±0.31	43.2
Hanamkonda	7.0±0.6^a	25.0±1.1^b	6.8±0.5^a	27.0±1.0^b	7.2±0.5^a	26.0±1.2^b	7.0±0.36	26.0±0.31	46.2
Mulugu	5.5±0.5^a	23.0±1.0^b	5.8±0.5^a	24.5±1.1^b	6.0±0.5^a	22.5±1.0^b	5.77±0.35	23.33±0.34	50.7
Jayashankar Bhupalpally	8.0±0.6^a	28.0±1.1^b	7.5±0.5^a	27.5±1.0^b	7.8±0.5^a	26.0±1.2^b	7.77±0.36	27.17±0.33	42.9

highlighted the effectiveness of IPM in managing thrips populations and enhancing chilli yield and profitability across diverse districts. IPM plots consistently recorded 42.9–50.7% lower thrips incidence compared with FP, with Mulugu showing the maximum reduction (Kaur et al., 2020). Stability of IPM effects across years indicates its robustness under variable agro-climatic conditions, supporting previous reports on the benefits of integrated approaches (Manideep et al., 2025). These findings underscore the efficacy of IPM in mitigating thrips pressure, which directly contributes to improved plant health and potential yield enhancement.

3.2. *Yield and other parameters analysis*

Chilli yields under IPM were consistently higher than FP across all years in all districts (Table 3). In Warangal, yields ranged from 20.1 to 23.3 t ha^{-1} under IPM, compared with 15.5–18.3 t ha^{-1} under FP, resulting in a pooled increase of 26.8%. Hanamkonda exhibited the largest relative yield gain (32.6%), with IPM yields of 17.0–19.1 t ha^{-1} versus 12.3–14.9 t ha^{-1} under FP. In Mulugu, IPM improved yields by 28.3% (20.4±0.63 t ha^{-1}) relative to FP (15.9±0.67 t ha^{-1}). Jayashankar Bhupalpally recorded moderate yield gains of 19.4% under IPM, with pooled means of 17.2±1.19 t ha^{-1} compared with 14.4±0.58 t ha^{-1} in FP. Overall, IPM adoption consistently enhanced productivity across districts and seasons, highlighting the combined benefits of effective pest suppression, improved crop management and agronomic interventions. Year-wise data confirmed the stability of IPM, maintaining higher productivity under variable seasonal conditions. Yield improvements under IPM ranged from 19.4% to 32.6%, with the highest gains in Hanamkonda, demonstrating the direct agronomic impact of pest suppression (Samreen et al., 2025). Economic analysis confirmed nearly double the B:C ratios under IPM compared with FP, highlighting its cost-effectiveness and resource-use efficiency (Kannan et al., 2019). The strong negative correlation between thrips incidence and yield (r=-0.876) reinforces the critical role of pest management in optimizing productivity (Mishra and Kumar, 2023).

Table 3: Comparative evaluation of chilli yield under integrated pest management (IPM) and farmer practice (FP) across four districts during *rabi,* 2022–2024

Year	2022		2023		2024		Pooled (Mean ± SE)		
District	IPM	FP	IPM	FP	IPM	FP	IPM	FP	% yield Increased
Warangal	20.1± 0.7^a	18.3± 0.7^b	20.4± 0.7^a	16.6± 0.7^b	23.3± 0.7^a	15.5± 0.7^b	21.3± 0.72	16.8± 0.64	26.8
Hanamkonda	18.8± 0.8^a	14.9± 0.7^b	17.0± 0.8^a	14.2± 0.7^b	19.1± 0.8^a	12.3± 0.7^b	18.3± 0.66	13.8± 0.78	32.6
Mulugu	21.0± 0.7^a	16.4± 0.6^b	20.5± 0.7^a	15.9± 0.7^b	19.8± 0.7^a	15.0± 0.7^b	20.4± 0.63	15.9± 0.67	28.3
Jayashankar Bhupalpally	19.3± 0.8^a	15.4± 0.7^b	15.2± 0.8^a	14.5± 0.7^b	17.0± 0.7^a	13.4± 0.7^b	17.2± 1.19	14.4± 0.58	19.4

3.3. *Economic analysis*

Economic evaluation demonstrated that IPM significantly improved profitability over FP across all districts and years. Gross returns under IPM ranged from ₹ 280,000 to ₹ 310,500 ha^{-1}, with B:C ratios between 2.20 and 2.42, while FP returns varied from ₹ 190,100 to ₹ 214,000 ha^{-1} with B:C ratios of 1.22–1.35 (Figure 1). ANOVA confirmed a highly significant effect of treatment on economic returns (F=152.7, p<0.001), whereas year (F=2.03, p=0.153) and treatment year interaction (F=1.05, p=0.369) were not significant. Pearson correlation analysis (Figure 2) revealed a strong negative association between thrips population and chilli yield (r=-0.876, p<0.001), emphasizing that pest suppression directly contributed to higher productivity and profitability. These results demonstrate that IPM not only effectively controls thrips but also ensures stable and enhanced economic returns, providing a sustainable, cost-

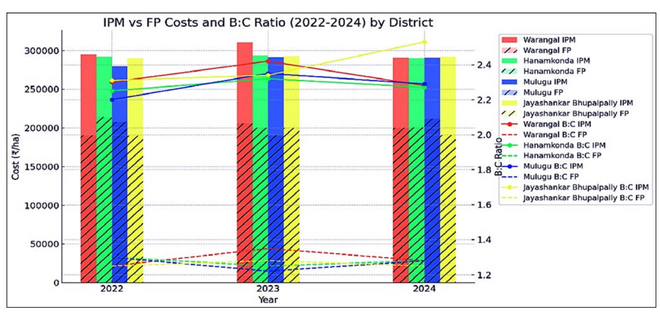

Figure 1: Economic returns and cost–benefit (B:C) ratios of chilli IPM vs FP across four districts during *rabi,* 2022–2024

efficient strategy for chilli cultivation. Overall, adoption of IPM ensured effective pest control, improved yield stability, and superior economic returns, validated as a sustainable and climate-smart strategy for chilli cultivation (Wyck Huys et al., 2020). These findings provide strong empirical support for promoting IPM adoption among smallholder

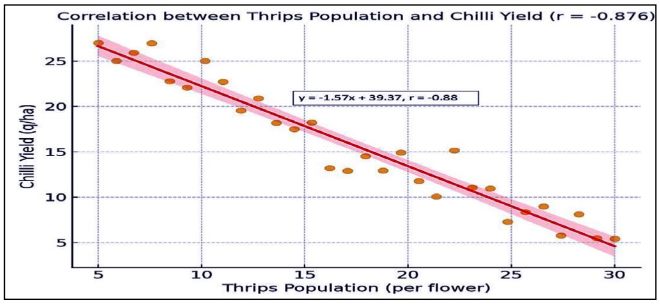

Figure 2: Pearson correlation analysis between thrips dynamics and yield during *rabi,* 2022–24

and commercial growers to achieve both agronomic and economic benefits.

3.4. *Technology adoption and yield gaps*

The analysis of chilli productivity under Integrated Pest Management (IPM) and conventional Farmer Practice (FP) across four districts revealed substantial differences in technology adoption, yield potential, and productivity gaps (Table 4). The technology gap (TG), representing the difference between potential yield (Yp) and yield obtained under improved technology (Yt), ranged from 0.6 to 2.1 t ha^{-1}. Mulugu recorded the lowest TG (0.6 t ha^{-1}), indicating that IPM practices in this district closely approached the potential yield. In contrast, Jayashankar Bhupalpally exhibited the highest TG (2.1 t ha^{-1}), suggesting that further optimization or local adaptation of IPM practices could improve outcomes. The extension gap (EG), reflecting the difference between IPM yield (Yt) and farmers' yield under conventional practice (Yf), varied from 2.8 to 4.5 t ha^{-1} (Figure 3). The largest gaps were observed in Warangal, Hanamkonda, and Mulugu (4.5 t ha^{-1}), highlighting the significant yield gains achievable through full adoption of IPM. Jayashankar Bhupalpally showed a smaller EG (2.8 t ha^{-1}), possibly due to partial adoption or location-specific constraints. The technology index (T_I), which measures the degree to which the improved technology achieves its potential yield, ranged from 2.86% to 10.88%. Mulugu had the lowest T_I (2.86%), indicating high suitability and effectiveness of IPM in this district, while Jayashankar Bhupalpally had the highest T_I (10.88%), reflecting moderate scope for further improvement. The yield gap (YG), defined as the difference between potential yield and farmers' yield, ranged from 4.9 to 6.5 t ha^{-1}, corresponding to 24.3–27.9% of potential yield. Warangal exhibited the highest YG (6.5 t ha^{-1}; 27.9%), indicating considerable untapped productivity, whereas Mulugu had the lowest YG (5.1 t ha^{-1}; 24.3%), suggesting better adoption of improved practices (Anusha et al., 2024).

Table 4: Comparison of potential, IPM, and farmer practice yields with yield gaps and technology indices across districts

District	Potential yield (t ha^{-1})	Yield in IPM (t ha^{-1})	Yield in FP (t ha^{-1})	Technology gap (t ha^{-1})	Extension gap (t ha^{-1})	Technology index (%)	Yield gap (t ha^{-1})	Increased yield in IPM (%)
Warangal	23.3	21.3	16.8	2.0	4.5	8.58	6.5	27.9
Hanamkonda	19.1	18.3	13.8	0.8	4.5	4.19	5.3	27.7
Mulugu	21.0	20.4	15.9	0.6	4.5	2.86	5.1	24.3
Jayashankar Bhupalpally	19.3	17.2	14.4	2.1	2.8	10.88	4.9	25.4

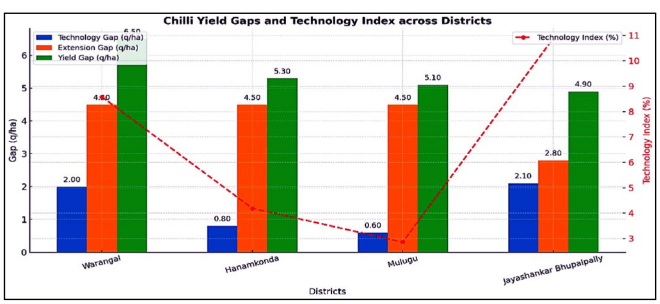

Figure 3: Yield performance and gaps under IPM and farmer practice across districts

The study demonstrated that IPM substantially improved chilli productivity compared to conventional FP across four districts by narrowing technology and extension gaps. The technology gap (TG) ranged from 0.6–2.1 t ha^{-1}, with Mulugu showing minimal TG (0.6 t ha^{-1}) and Jayashankar Bhupalpally the highest (2.1 t ha^{-1}), indicating variability in IPM effectiveness and the need for local adaptation (Jaya et al., 2025). Extension gaps (EG) of 2.8–4.5 t ha^{-1} highlighted the potential yield gains achievable through full adoption of IPM, particularly in Warangal, Hanamkonda, and Mulugu. Technology index (T_I) values (2.86–10.88%) and yield gaps (YG, 24.3–27.9%) further underscored differences in performance and untapped productivity (Rani, 2020; Singh and Sharma, 2019). Overall, districts with lower TG and T_I, such as Mulugu and Hanamkonda, approached near-optimal yields, whereas Warangal and Jayashankar Bhupalpally require strengthened extension support and site-specific IPM optimization to enhance chilli productivity sustainably. Overall, these findings indicated that IPM effectively narrowed both technology and extension gaps while enhancing productivity (Muralimohan et al., 2023). Districts such as Mulugu and Hanamkonda demonstrated near-optimal performance under IPM, whereas Warangal and Jayashankar Bhupalpally could benefit from strengthened extension support and localized adaptation strategies. The combined assessment of TG, EG, T_I and YG highlights the potential yield gains and provides actionable insights for targeted interventions to promote sustainable chilli production.

4. CONCLUSION

The three-year study revealed that Integrated Pest Management (IPM) effectively suppressed black thrips in chilli, keeping populations below 8 flower^{-1} and reducing incidence by 42.9–50.7% across districts. This resulted in 19.4–32.6% higher yields and nearly double B:C ratios compared to Farmer Practice, confirming its economic advantage. Gap analysis indicated Mulugu and Hanamkonda neared potential yields, while Warangal and Jayashankar Bhupalpally required focused support. IPM proved sustainable, cost-effective, and climate-resilient for chilli production.

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