

ISSN Print: 2664-844X
ISSN Online: 2664-8458
NAAS Rating (2026): 4.97
IJAFS 2026; 8(10): 665-668
www.agriculturaljournals.com
Received: 02-08-2026
Accepted: 05-09-2026
Published: 16-10-2026

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Field evaluation of integrated pest management (IPM) modules against terrestrial snails

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DOI: https://www.doi.org/10.33545/2664844X.2026.v8.i10i.2077

Abstract
The current study was carried out in a naturally infested soybean plot at Sadoli Khalsa (Karvir Taluka, Kolhapur District, Maharashtra) during the Kharif season of 2025. The field experiment followed a Randomised Block Design (RBD) with 9 integrated management treatments as a viable alternative to broadcast chemical applications, replicated three times. The collected data were analysed statistically using square root transformation to estimate mean snail survival at 3, 7, and 14 Days After Placement (DAP). The overall mean survival of snails across all observation intervals clearly indicated that the T_1 treatment (manual collection + beer bait + metaldehyde dry pellet 2.5%) was the most effective IPM practice, recording the lowest overall mean survival of 0.60 snails. This was closely followed by the T_2 treatment (wheat bran bait) with 0.79 snails and the T_4 treatment (fruit bait) with 0.97 snails. In contrast, standard insecticidal spray treatments demonstrated moderate to low efficacy, with survival ranging from 1.56 to 1.63 snails. Thus, the integration of physical canopy clearance with intensely aromatic containment traps and localized chemical borders guarantees vastly superior population suppression when benchmarked against isolated chemical deployment.

Keywords: Integrated Pest Management, Terrestrial snails, Soybean, Metaldehyde, Attractant baits, Significant

Introduction

The molluscan phylum, predominantly consisting of the class Gastropoda, ranks as the second-largest group of animals on Earth (Chatterjee *et al.*, 2024) [1]. Upon exceeding typical density thresholds, these terrestrial snails mutate into highly destructive polyphagous pests capable of consuming upward of 500 varied plant types (Jadhav *et al.*, 2016; Bhattacharyya *et al.*, 2014) [3, 2]. The physical grazing of these pests inflicts immediate botanical trauma, triggering vast downstream economic deficits (Chavan, 2024) [4], with regions across Maharashtra recently documenting disastrous population explosions that have compromised more than 72,000 hectares of seasonal Kharif plantings, particularly soybean (Neharkar *et al.*, 2025) [5]. Standard mitigation protocols have heavily leaned on synthetic chemical molluscicides, such as metaldehyde pellets, alongside broad-spectrum foliar insecticides; however, deploying these manufactured chemicals independently carries profound practical limitations. Because target gastropods feed most actively amidst intense humidity and heavy monsoon rains, scattered chemical treatments rapidly degrade or wash away (Sallam *et al.*, 2012) [6]. Furthermore, these chemicals completely lack the natural olfactory attraction necessary to pull targeted pests; without an actively fermenting substrate, snails frequently bypass the raw toxicant entirely (Raut *et al.*, 1984; Smith *et al.*, 2013) [7, 8], while unregulated environmental broadcasting creates intense hazards for non-target livestock and aquatic networks (Lucero, 2021; Elfoudali *et al.*, 2024) [10, 9]. Overcoming these profound challenges dictates a transition toward comprehensive Integrated Pest Management (IPM) structures that synchronize strict physical hand-picking with strategically placed, odour-based attractant traps (Chatterjee *et al.*, 2024; Elfoudali *et al.*, 2024) [1, 9]. By exploiting the acute scent-tracking capabilities of gastropods utilizing highly volatile, fermenting biological attractants, pests can be aggressively drawn out of daytime refuges and exposed to lethal barriers (Veasey *et al.*, 2021) [11], a strategy that has previously achieved absolute eradication within seventy days when synced with targeted metaldehyde application (Patil *et al.*, 2015) [12]. Consequently, the current field experiment was organized to rigorously evaluate the real-world performance of these integrated IPM modules against standard insecticidal sprays to establish a highly effective management strategy in soybean ecosystems.

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Materials and methods

Experimental Site and Layout: A field experiment was conducted during August and September of the 2025 Kharif season in a naturally infested soybean (*Glycine max* L.) plot located at Sadoli Khalsa (Karvir Taluka, Kolhapur District, Maharashtra, India). The trial was laid out in a Randomised Block Design (RBD) with three replications. The experimental area was divided into 27 individual plots, each measuring 5.0 m × 4.0 m (20.0 m^2), with a crop spacing of 45 cm × 15 cm. An inter-plot isolation buffer of 1.0 m was maintained to prevent toxicant residue movement and lure cross-interference.

Treatment Details: Nine treatments were evaluated, consisting of integrated management modules, chemical standards, and an untreated control. The integrated modules (T_1 through T_6) combined three simultaneous interventions:

- Mechanical Knockdown: Manual collection of adult and juvenile snails from foliage and soil bases, standardised at 1 man-hour per plot (20 m^2) during peak early morning foraging hours (5:00 AM to 6:30 AM). Collected snails were subsequently placed in sealed collection bags and safely disposed of by deep burial.
- Poison Baits: A custom-engineered, weatherproof cylindrical container trap (25 cm height, 16 cm basal width) was installed in each designated trap plot. Traps were buried 6 cm deep to ensure the entry ramps rested flat on the soil surface. These were loaded with specific food bases, 20 g of active dry yeast as a fermentation catalyst, and 50 g of 2.5% metaldehyde pellets. Traps were inspected, cleaned of dead snails, and replenished every 5 days.
- Contact Barriers: Uniform broadcasting of 2.5% metaldehyde dry pellets along plot borders and canopy ground zones at an application rate of 2 g/m^2 to act as a lethal contact barrier against migrating snails.

For comparison, two commercial foliar insecticides were applied using a high-pressure knapsack sprayer equipped with a hollow cone nozzle during calm morning conditions: Thiamethoxam 12.6% ZC + Lambda-cyhalothrin 9.5% ZC applied at 0.5 mL/L (T_7), and Imidacloprid 40% WG + Fipronil 40% WG applied at 1.0 g/L (T_8).

Observation and Statistical Analysis: To evaluate pest suppression with micro-spatial accuracy, 10 designated plants were tagged centrally in each plot. Pre-treatment counts of live snails were conducted 24 hours prior to treatment imposition to verify uniform initial infestation levels across all 27 experimental units. Post-treatment observations of surviving snails were recorded at 3, 7, and 14 Days After Placement (DAP). These observations were taken exclusively during early morning hours (5:00 AM to 7:00 AM) before thermal elevation caused the snails to descend into soil crevices. The raw mean population data were normalized utilizing Square Root Transformation ($\sqrt{x+0.5}$) and subjected to Analysis of Variance (ANOVA) for RBD, with treatment efficacy compared using the Critical Difference (CD) at a 5% level of probability.

Table 1. Details of Integrated Pest Management (IPM) practices used in the experiment.

Treatment no.	IPM Details
T_1	Manual collection + Beer Bait + metaldehyde dry pellet 2.5%.
T_2	Manual collection + Wheat bran bait + metaldehyde dry pellet 2.5%.
T_3	Manual collection + Rice bran bait + metaldehyde dry pellet 2.5%.
T_4	Manual collection + Fruit bait + metaldehyde dry pellet 2.5%.
T_5	Manual collection + Cabbage bait + metaldehyde dry pellet 2.5%.
T_6	Manual collection + Metaldehyde bait + metaldehyde dry pellet 2.5%.
T_7	Insecticide spraying (Thiamethoxam 12.6% ZC + Lambda-cyhalothrin 9.5% ZC)
T_8	Insecticide spraying (Imidacloprid 40% WG + Fipronil 40%WG)
T_9	Water (Control).

Result and discussion

Efficiency of integrated pest management (IPM) practices

Preliminary infestation assessments completed before treatment rollout showed starting densities ranging between 2.20 and 2.37 snails per observation unit. Statistical variance across these preliminary blocks proved non-significant, verifying a completely homogeneous pest distribution throughout the testing zone before initiating the research.

During the day three checkpoint (3 DAP), every applied IPM module registered substantial pest depletion relative to the unmanaged plots. Treatment T_1 (manual collection + beer bait + metaldehyde dry pellet 2.5%) emerged as the apex performer, leaving a mere 0.63 surviving snails. Statistically, this result mirrored T_2 (manual collection + wheat bran bait + metaldehyde dry pellet 2.5%) and T_4 (manual collection + fruit bait + metaldehyde dry pellet 2.5%), which permitted 0.80 and 1.03 snail survivals, respectively. The untreated control showed the highest mean survival of 2.20 snails among all treatments at this interval.

The observations recorded at 7 DAP and 14 DAP confirmed the sustained effectiveness of the integrated baiting treatments. The data on the overall mean survival of snails across all the observation intervals clearly indicated that the T_1 treatment was the most effective IPM practice, recording the lowest overall mean survival of 0.60 snails. This was closely followed by the T_2 treatment (0.79 snails) and the T_4 treatment (0.97 snails). Conversely, the foliar application of commercial insecticides—Thiamethoxam 12.6% ZC + Lambda-cyhalothrin 9.5% ZC (T_7) and Imidacloprid 40% WG + Fipronil 40% WG (T_8)—displayed highly inadequate mitigation, recording mean snail survivals of 1.56 and 1.63, respectively. The untreated control maintained a high overall mean survival rate of 2.19 snails.

The clear supremacy of integrated protocols underscores the value of adopting a holistic IPM framework. The initial step of physical handpicking delivered an immediate mechanical blow by actively stripping a massive volume of the pest burden directly from the canopy. Following this clearance, potent aromatic attractants (such as fermenting beer or wheat bran) successfully drew hidden remnants into the open, directly exposing them to the deadly metaldehyde pellets. The results obtained in the present study are consistent with those reported by Muniappan *et al.* (1986), Patil *et al.* (2015) [12], and Paul *et al.* (2016) [13].

In contrast, commercial foliar insecticidal applications (T_7 and T_8) displayed highly inadequate mitigation. Although compounds like fipronil or neonicotinoids carry inherent toxicity, they must be engineered into edible, highly palatable bait stations rather than broadly sprayed to achieve genuine field success. The present findings regarding the failure of foliar sprays against terrestrial snails are in conformity with the results reported by Eshra *et al.* (2016) [14] and Gadekar *et al.* (2024) [15]. Ultimately, integrating physical removal with highly attractive baits and the targeted broadcasting of molluscicides provides the most viable and effective management strategy, a trend that was also observed by Rusli *et al.* (2023) [16].

DAP- Days after placement. *Figures in parentheses are $\sqrt{x}$ + 0.5 transformed values.

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Table 2. Integrated Pest Management (IPM) practices against snails

Treatment No.	Treatment	Pre-Count	Mean no. of snail survival			
			3 DAP	7 DAP	14 DAP	Mean
1	Collection + Beer Bait + metaldehyde dry pellet 2.5%	2.33 (1.68) *	0.63 (1.05)	0.57 (1.03)	0.60 (1.04)	0.60 (1.05)
2	Collection + Wheat bran bait + metaldehyde dry pellet 2.5%	2.30 (1.67)	0.80 (1.13)	0.73 (1.11)	0.83 (1.14)	0.79 (1.14)
3	Collection + Rice bran bait + metaldehyde dry pellet 2.5%	2.20 (1.64)	1.23 (1.31)	1.17 (1.28)	1.13 (1.27)	1.18 (1.30)
4	Collection + Fruit bait + metaldehyde dry pellet 2.5%	2.30 (1.67)	1.03 (1.24)	0.97 (1.21)	0.90 (1.18)	0.97 (1.21)
5	Collection + Cabbage bait + metaldehyde dry pellet 2.5%	2.23 (1.65)	1.37 (1.36)	1.40 (1.37)	1.43 (1.38)	1.4 (1.38)
6	Collection + Metaldehyde bait + metaldehyde dry pellet 2.5%	2.27 (1.66)	1.27 (1.33)	1.23 (1.31)	1.30 (1.34)	1.27 (1.33)
7	Insecticide spraying (Thiamethoxam 12.6% ZC+ Lambda cyhalothrin 9.5% ZC)	2.37 (1.69)	1.57 (1.44)	1.53 (1.42)	1.57 (1.44)	1.56 (1.44)
8	Insecticide spraying (Imidacloprid 40% WG + Fipronil 40%WG)	2.23 (1.65)	1.67 (1.47)	1.60 (1.45)	1.63 (1.46)	1.63 (1.46)
9	Control	2.27 (1.66)	2.20 (1.64)	2.17 (1.63)	2.20 (1.64)	2.19 (1.64)
SE		0.08	0.08	0.07	0.07	0.07
CD at 5%		NS	0.23	0.20	0.22	0.22
CV%		8.1	10.06	8.86	9.44	9.45

Summary and conclusion

The field investigation evaluated multi-component Integrated Pest Management (IPM) practices as viable alternatives to broadcast chemical applications for suppressing pestiferous land snail populations. Results demonstrated that combined baiting architectures drastically diminished pest densities when compared against completely unmanaged baseline plots. Treatment T_1 (integrating manual collection, beer lures, and scattered 2.5% metaldehyde pellets) proved overwhelmingly superior, recording the lowest overall mean snail survival of 0.60. This was closely followed by the T_2 framework (manual collection plus wheat bran plus metaldehyde) with an overall mean survival of 0.79, and the T_4 framework (manual collection plus fruit lure plus metaldehyde) with 0.97. Conversely, standard commercial foliage sprays—namely Thiamethoxam 12.6% ZC + Lambda-cyhalothrin 9.5% ZC (T_7) and Imidacloprid 40% WG + Fipronil 40% WG (T_8)—exhibited weak mitigation capabilities, recording high mean snail survivals of 1.56 and 1.63, respectively. The unmanaged baseline consistently harboured the maximum density of surviving individuals throughout the entire tracking window, recording an overall mean of 2.19. Ultimately, the research solidifies that depending strictly upon standard synthetic foliar applications yields grossly insufficient mollusc mitigation. Unifying physical canopy clearance (hand-picking) with intensely aromatic containment traps and localised chemical borders guarantees vastly superior, enduring population suppression when benchmarked against isolated chemical deployment.

Acknowledgements

I gratefully acknowledge the Department of Entomology, Rajarshee Chhatrapati Shahu Maharaj Government College of Agriculture, Kolhapur, for providing the facilities to conduct this research and thank all teachers, technical staff and colleagues for their support and cooperation.

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How to cite this article: Gawas DA, Bagde AS, Barve AN, Pawar MS, Ballal MM, Ekatpure TP. Field evaluation of integrated pest management (IPM) modules against terrestrial snails. *International Journal of Agriculture and Food Science*. 2026;8(10):665-668. doi: https://www.doi.org/10.33545/2664844X.2026.v8.i10i.2077

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