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Research Article

Evaluation of biorational products against insect pests of cashew (*Anacardium occidentale* L.)

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ABSTRACT: Cashew (*Anacardium occidentale* L.), a vital cash crop in India, faces significant yield losses due to pests like Tea Mosquito Bug (TMB; *Helopeltis antonii* Sign), thrips, and Shoot Tip Caterpillar (STC). Synthetic pesticides, though effective, pose environmental and health risks, necessitating eco-friendly alternatives. This study evaluated the efficacy of botanical extracts and cow urine-based formulations against major cashew pests in Bastar, Chhattisgarh, during 2020-22. Field experiments tested nine treatments, including *Datura metel* (3%), *Andrographis paniculata* (3% and 5%), cow urine + mixed leaves putrefaction (3%), and a synthetic control (λ-cyhalothrin 0.6 ml/l), arranged in a randomized block design. Results showed *D. metel* 3% decoction most effectively reduced TMB (67.1%), thrips (83.3%), and leaf miner (81.6%) damage. *A. paniculata* 5% minimized leaf folder damage (47.6%) and achieved the highest yield (0.803 t/ha), while cow urine + mixed leaves reduced STC infestation by 46.5%. Though synthetic insecticide outperformed botanicals (TMB reduction: 80.2%), *D. metel* and *A. paniculata* demonstrated comparable efficacy with added sustainability benefits. The study concludes that plant-derived botanicals, particularly *Datura metel* 3% and *Andrographis paniculata* 5%, offer viable, low-toxicity alternatives for integrated pest management in organic cashew cultivation, balancing productivity and ecological safety.

KEYWORDS: *Andrographis paniculata*, *Datura metel*, botanical, tea mosquito bug, yield

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INTRODUCTION

Cashew (*Anacardium occidentale* L.) is an important cash crop that belongs to the family Anacardiaceae and native of North - East Brazil in South America. India accounts for 25% of the world's Raw Cashew Nuts (RCN) production with 1.06 million acres under cashew cultivation (Preethi *et al*., 2021). However, cashew plantations often face significant productivity challenges due to infestations by major insect pests, leading to substantial economic losses and reduced harvest quality. Key pests affecting cashew in Bastar, Chhattisgarh, include the tea mosquito bug (TMB-*Helopeltis antonii* Sign), inflorescence thrips, Leaf Folder (LF), Shoot Tip Caterpillar (STC) and Leaf Miner (LM) (Jairam *et al*., 2021). Effective pest management is essential for sustainable cashew production, and while synthetic insecticides are effective, their high toxicity poses risks to human health and the environment, making plant-derived botanicals a safer, eco-friendly alternative that degrades more quickly and is less harmful to beneficial insects (Dougoud *et al*., 2019). Bastar region of Chhattisgarh showcases diverse species like Neem, Tulsi, Dhatura, Akarkara, Milkweed, and Garari, all valued for their insecticidal properties and traditional pest management uses (Pandey *et al*., 2018). Despite the potential utility of these plant extracts in managing insect pests of cashew, their application in this context has yet to be thoroughly investigated.

MATERIALS AND METHODS

An experiment was carried out during the years 2020-21 and 2021-22 at Cashew Research Field, Shaheed Gundadhoor College of Agriculture and Research Station (IGKV), Jagdalpur, and NURI Farm, Lamker, Chhattisgarh

to study the field efficacy of different botanicals *viz*. *Andrographis paniculata* decoction 3%, *Andrographis paniculata* decoction 5%, *Calotropis gigantean* decoction 3%, *Datura metel* decoction 3%, cow urine + mixed leaves putrefaction 3%, mixed leaves decoction 3*%* [mixed leaves {*Andrographis* + *Calotropis* + *Cascabela* + *Datura* + *Pongamia* + *Ipomoea* + *Lantana* + *Azadirachta indica* (each 100g to prepare 1kg final weight)}], AAVYA 4 g/l (commercial biopesticide formulation), recommended insecticide λ- cyhalothrin 5 EC (0.6 ml/l), and untreated check. The plantations of cashew variety Vengurla-4 planted in both farms with a spacing of 7 x 7 m were selected for recording the incidence of pests. The experiment was designed in a randomized complete block design with 9 treatments and 3 replications; each treatment was imposed in 3 trees per replication. Treatments were sprayed two times, *i.e.*, during the flowering and fruiting stages of crop and pre observations were recorded before spray and after each sprays post observations were taken at an interval of 15 days in the morning hours during the season. Observations were recorded as per the proceedings of the AICRP on cashew proceedings (Anonymous, 2012). The damage caused by the TMB and thrips was assessed using a 0-4 scale Damage Score (DS) as suggested by Jalgaonkar *et al*. (2009). For STC, LF and LM, total numbers of infested and healthy leaves per shoot among the 24-52 marked leader shoots were counted and per cent infestation computed (Nirala *et al*., 2019; Jairam *et al*., 2021).Reduction percentages of DS and damage per cent of various pests for all the treatments were corrected according to Henderson and Tilton's formula (Henderson& Tilton, 1955). After carrying out Bartlett's test for homogeneity of variance, the two years and two locations data were pooled. All the observations on damage score were square root transformed, and per cent damage was arc sin transformed and subjected to ANOVA using OPSTAT (Sheoran *et al.,*1998).

RESULTS

The field evaluation of various biorational products included fermented leaf preparations, indigenous formulations, and a chemical insecticide against the incidence of Tea Mosquito Bug (TMB), thrips, Shoot Tip Caterpillar (STC), Leaf Miner (LM) and Leaf Folder (LF) in cashew revealed considerable variation in their efficacy (Tables 3,4). The treatments exerted significant influence on the post-treatment damage scores, reduction percentages, and ultimately the yield. A detailed interpretation of these findings is presented.

Table 1. Damage score for tea mosquito bug (as suggested by Jalgaonkar *et al*., 2009)

Score	Description of the damage
0	No lesions/streaks
1	1 to 3 necrotic lesions/streaks
2	4 to 6 coalescing or non-coalescing lesions/streaks
3	Above 6 coalescing or non-coalescing lesions/streaks
4	Lesions /streaks confluent or wilting affected shoots/panicles

Table 2. Damage score for Thrips (as suggested by Nirala *et al*., 2019; Jairam *et al*., 2021)

Score	Details
0	No Damage
1	1-25% nut or apple surface damaged (up to 1/4 of the damaged surface area)
2	26-50% nut or apple surface damaged (up to 1/2 of the damaged surface area)
3	51-75% nut or apple surface damaged (up to 3/4 of the damaged surface area)
4	76-100% nut or apple surface damaged (more than 3/4 of the damaged surface area)

Table 3. Efficacy of botanicals against TMB and Thrips in cashew during 2020-21 and 2021-22 (pooled over 2 years)

Treatments	Damage score of TMB			Damage score of thrips			Yield (t/ ha)
	Pre treatment DS (0-4)	Post treatment DS (0-4)	R (%)	Pre treatment DS (0-4)	Post treatment DS (0-4)	R (%)	
T_1- *Andrographis paniculata* decoction 3 %	1.99(1.72)	1.33(1.50)	31.89	0.88(1.36)	0.60(1.12)	65.91	0.767
T_2 - *Andrographis paniculata* decoction 5 %	2.17(1.78)	0.79(1.32)	62.90	0.86(1.36)	0.36(1.08)	79.07	0.803
T_3-*Calotropis gigantea* decoction 3 %	2.07(1.75)	1.51(1.57)	25.66	1.15(1.46)	0.74(1.15)	67.83	0.769
T_4-*Datura metel* decoction 3 %	1.27(1.50)	0.41(1.18)	67.10	0.78(1.32)	0.26(1.08)	83.33	0.777
T_5-Cow urine+ mixed leaves putrefaction 3 %	1.50(1.58)	0.60(1.25)	59.24	0.99(1.41)	0.36(1.09)	81.22	0.749
T_6- Mixed leaves decoction 3 %	2.38(1.83)	1.24(1.48)	46.91	0.90(1.37)	0.56(1.14)	68.89	0.726
T_7-AAVYA (4g/l)	2.09(1.74)	1.43(1.54)	30.28	0.77(1.33)	0.84(1.13)	45.00	0.736
T_8-λ-cyhalothrin 5EC (0.6ml/l)	1.80(1.67)	0.35(1.16)	80.19	0.85(1.36)	0.17(1.05)	90.00	0.855
T_9 - Untreated check	2.14(1.77)	2.10(1.75)		0.73(1.31)	1.46(1.31)		0.594
Mean	1.93	1.08		0.88	0.59		
SE(m)±	0.07	0.07		0.03	0.03		
CD (p=0.05)	NS	0.20		NS	0.09		
CV (%)	8.19	9.50		5.76	5.42		

Note: TMB - Tea mosquito bug, R (%) - reduction per cent, DS - Damage score, NS - Non significant,

Values in the parentheses are square root transformed values.

Performance against TMB

The pre-treatment pooled mean damage scores of TMB were statistically comparable across treatments, ranging narrowly between 1.27 and 2.38, indicating uniform initial infestation (Table 3, Figure 1). Following the application of treatments, substantial reductions were observed in several botanical and chemical options. Among all treatments, λ-cyhalothrin 5EC (T_8) recorded the lowest post-treatment damage score of 0.35, corresponding to the highest reduction of 80.19%, demonstrating its superior efficacy in suppressing TMB infestation. This aligns with its known quick knockdown and residual effect on sucking pests.

Among botanicals, *Datura metel* decoction 3% (T_4) performed remarkably well, achieving a post-treatment damage score of 0.41 and a high reduction of 67.10%,

Table 4. Efficacy of botanicals against STC, LM and LF of cashew during 2020-21 and 2021-22 (pooled over 2 years)

Treatments	Damage percentage of STC			Damage percentage of LM			Damage percentage of LF		
	Pre treatment %	Post treatment %	R (%)	Pre treatment %	Post treatment %	R (%)	Pre treatment %	Post treatment %	R (%)
T_1 - *Andrographis paniculata* decoction 3 %	5.53 (8.87)	4.07 (11.56)	9.01	2.38 (8.87)	0.83 (5.20)	59.76	2.52 (9.08)	1.60 (7.25)	19.74
T_2 - *Andrographis paniculata* decoction 5 %	6.91 (9.14)	3.66 (10.91)	34.52	2.54 (9.14)	0.64 (4.43)	70.93	2.75 (9.45)	1.14 (6.07)	47.60
T_3-*Calotropis gigantea* decoction 3 %	5.15 (8.89)	2.92 (9.75)	29.90	2.40 (8.89)	0.83 (5.11)	60.10	2.23 (8.59)	2.00 (8.06)	13.37
T_4-*Datura metel* decoction 3 %	7.11 (8.80)	3.60 (10.87)	37.40	2.38 (8.80)	0.38 (3.46)	81.58	2.33 (8.74)	1.29 (6.40)	30.02
T_5-Cow urine+ mixed leaves putrefaction 3 %	8.92 (8.66)	3.86 (11.22)	46.50	2.28 (8.66)	0.58 (4.32)	70.65	2.20 (8.46)	1.35 (6.62)	22.43
T_6-mixed leaves decoction 3 %	7.06 (8.59)	4.18 (11.62)	26.80	2.25 (8.59)	0.53 (4.09)	72.82	2.04 (8.13)	1.34 (6.42)	16.97
T_7-AAVYA (4g/l)	5.42 (9.39)	3.50 (10.75)	20.17	2.67 (9.39)	1.68 (7.30)	27.40	2.52 (9.09)	1.69 (7.34)	15.23
T_8-λ-cyhalothrin 5EC (0.6ml/l)	6.38 (8.71)	1.47 (5.20)	71.52	2.30 (8.71)	0.19 (2.40)	90.47	2.27 (8.62)	0.69 (4.76)	61.58
T_9 - Untreated check	5.86 (8.60)	4.74 (12.41)		2.25 (8.60)	1.95 (7.71)		2.25 (8.49)	1.78 (7.54)	
Mean	6.48	3.56		2.38	0.84		2.34	1.43	
SE(m)±	0.31	0.51		0.36	0.19		0.54	0.20	
CD (p=0.05)	NS	1.49		NS	0.55		NS	0.60	
CV (%)	7.54	9.87		7.14	7.95		12.40	6.08	

making it the most effective botanical treatment (Table 3, Figure 1). This suggests that Datura's alkaloids, particularly atropine and scopolamine, may contribute to strong insecticidal activity.

The second tier of promising botanical treatments includes *Andrographis paniculata* decoction at 5% (T_2), which resulted in a TMB reduction of 62.90% and a post-treatment score of 0.79, indicating substantial control potential (Table 3). The cow urine + mixed leaves putrefaction (T_5) also performed satisfactorily with a 59.24% reduction, suggesting that fermentation-derived bioactive metabolites may have contributed to pest suppression.

Moderate efficacy was observed in mixed leaves decoction (T_6) and *Calotropis gigantea* decoction (T_3),

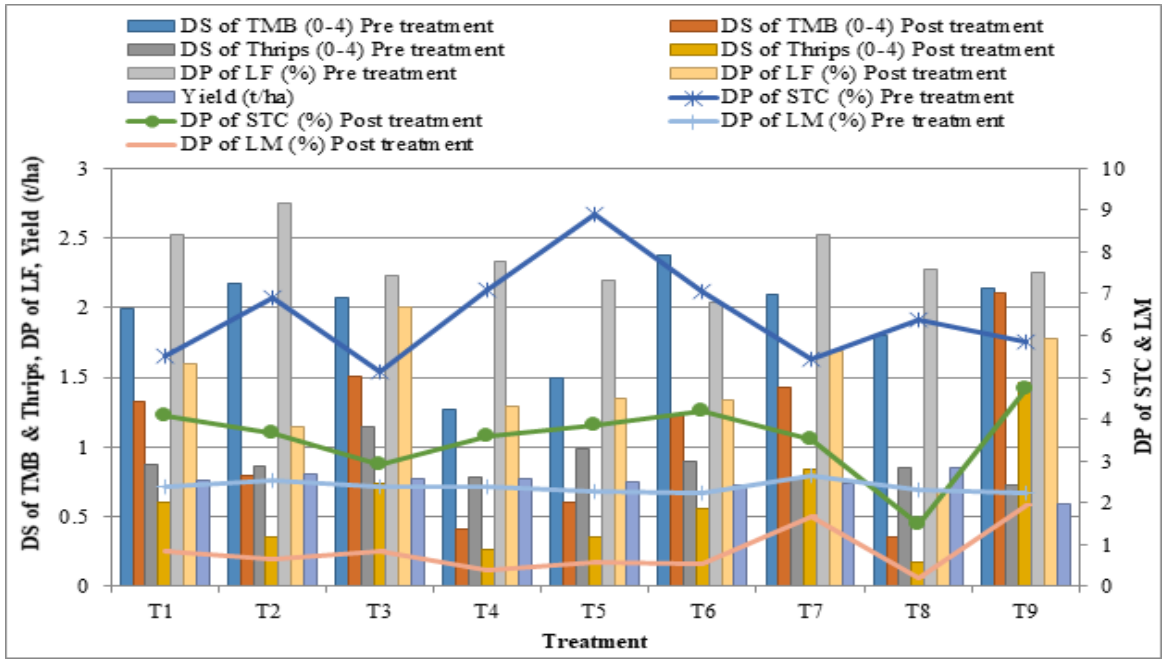


Figure 1. Effect of botanical and chemical treatments on insect damage and yield.

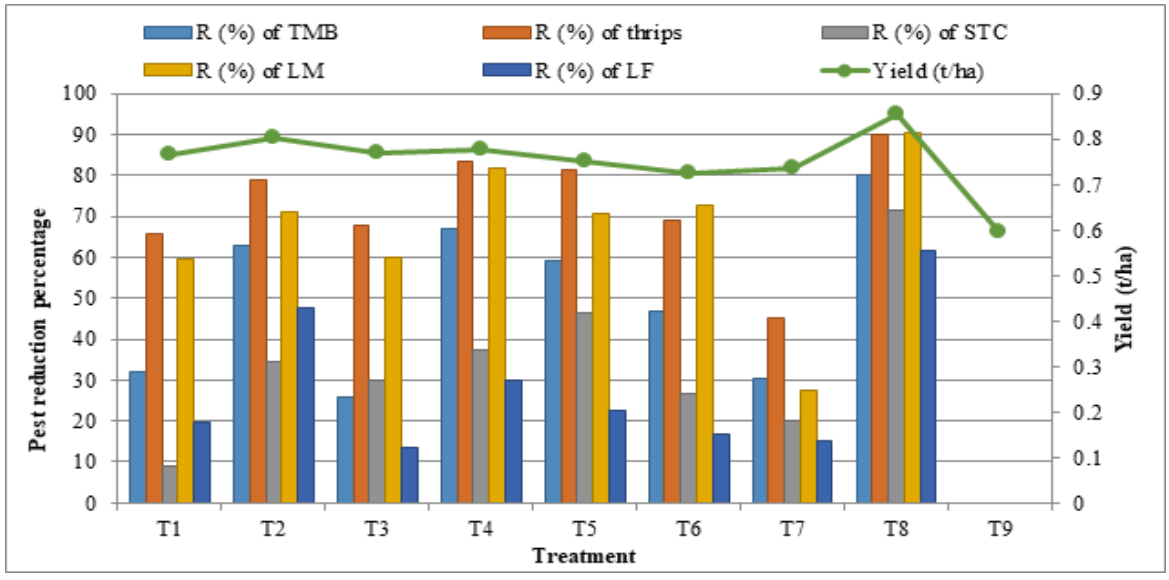


Figure 2. Comparative performance of treatments based on pest reduction percentage and yield (t/ha).

which accounted for 46.91% and 25.66% reduction, respectively (Table 3). Their comparatively lesser performance indicates mild insecticidal activity, possibly requiring higher concentrations or repeated applications for improved control.

The indigenous product AAVYA (T_7) provided only 30.28% reduction, placing it among the least effective treatments (Table 3). The untreated check (T_9) expectedly exhibited no reduction, with the post-treatment damage score remaining nearly unchanged (2.10).

The pooled mean values also reflected these trends, with the mean post-treatment damage score reducing from 1.93 to 1.08, confirming that the treatments collectively contributed to lowering TMB infestation (Table 3). The

Coefficient of Variation (CV) of 8.19% for pre- and 9.50% for post-treatment data indicates reliability and low experimental error.

Performance against thrips

As in the case of TMB, the pre-treatment thrips damage scores were closely aligned, ranging between 0.73 and 1.15 across treatments (Table 3, Figure 1). This uniformity ensured unbiased assessment of treatment impact.

Post-treatment evaluation revealed that λ-cyhalothrin 5EC (T_8) again registered the lowest damage score of 0.17, achieving a remarkable 90.00% reduction—the highest among all treatments (Table 3). This confirms its broad-spectrum efficacy against multiple sucking pests of cashew.

Among botanicals, *Daturametel*decoction (T_4) remained the most potent, with a post-treatment score of 0.26 and 83.33% reduction, surpassing all other natural treatments (Table 3). The cow urine + mixed leaves putrefaction (T_5) also performed well by achieving an 81.22% reduction, indicating that synergistic microbial metabolites may play a major role in thrips suppression.

The 5% *Andrographis* decoction (T_2) proved quite effective with 79.07% reduction, while the 3% decoction (T_1) achieved 65.91%, indicating a clear dose-dependent response (Table 3). Mixed leaves decoction (T_6) also provided moderate control, with a reduction of 68.89%. *Calotropis gigantea* decoction (T_3) reduced thrips damage by 67.83%, showing reasonable efficacy but still lower than Datura or cow urine-based treatments.

The AAVYA formulation (T_7) was among the least effective natural alternatives, achieving a reduction of only 45.00%, though still superior to the untreated check (Table 3). The untreated plot exhibited an increase in post-treatment thrips damage score (1.46), confirming ongoing pest pressure.

Performance against Shoot Tip Caterpillar (STC)

The pooled mean pre-treatment damage of STC ranged from 5.15% to 8.92% across treatments (Table 4), indicating relatively uniform initial pest pressure. Post-treatment observations, however, revealed considerable variation in pest suppression efficiency. The synthetic insecticide T_8- lambda-cyhalothrin 5EC achieved the highest reduction of 71.52%, bringing the post-treatment STC infestation down to 1.47%, the lowest among all treatments. This significant decline underscores the superior knockdown and residual effectiveness of the pyrethroid molecule.

Among botanical treatments, T_5- Cow urine + mixed leaves putrefaction (3%) showed the maximum reduction (46.50%), lowering pest damage from 8.92% to 3.86% (Table 4). This was followed by T_4-*Datura metel* decoction (3%) with 37.40% reduction, T_2- *Andrographis paniculata* decoction (5%) with 34.52%, and T_3-*Calotropis gigantea* decoction (3%) with 29.90% reduction. These performances demonstrate that certain botanicals have moderately high insecticidal or repellent properties against STC.

Lower efficacy was observed with T_6- mixed leaves decoction (26.80%) (Table 4), T_7- AAVYA (20.17%), and T_1-*A. paniculata* 3% (9.01%), indicating only marginal control. The untreated check exhibited a slight natural increase in pest damage (5.86% to 4.74%), reflecting normal field fluctuation. Based on pooled means, the overall average post-treatment damage (3.56%) was significantly lower than pre-treatment levels (6.48%), confirming that most treatments contributed to STC suppression.

Performance against Leaf Miner (LM)

Leaf miner infestation responded distinctly to different treatments. Pre-treatment damage values were narrow (2.25%-2.67%) (Table 4), indicating uniform initial incidence. The synthetic treatment T_8 again excelled with the highest reduction of 90.47%, lowering damage from 2.30% to a mere 0.19%—an extremely effective level of suppression. This reaffirms lambda-cyhalothrin's high systemic and contact activity against leaf-mining larvae.

Botanicals also demonstrated considerable potential. T_4-*Datura metel* (3%) recorded the second-highest reduction at 81.58% (Table 4), reducing damage to 0.38%. Close behind were T_2-*A. paniculata* (5%) with 70.93% and T_5- cow urine + leaves (70.65%). These values confirm that certain botanical extracts possess strong antifeedant and oviposition-deterrent properties effective against LM larvae.

Moderate suppression was recorded in T_6 (72.82%) and T_3 (60.10%) (Table 4). In contrast, T_7 (AAVYA) displayed only 27.40% reduction, showing limited suitability for leaf miner management. T_1- *A. paniculata* 3% also showed moderate reduction (59.76%). The untreated check showed slight variation between pre- and post-treatment (2.25% to 1.95%), attributable to natural factors.

Mean values revealed that LM post-treatment incidence was drastically lower (0.84%) compared to pre-treatment (2.38%), demonstrating an overall strong impact of treatments.

Performance against Leaf Folder (LF)

Leaf folder infestation showed a similar trend to STC and LM, with the synthetic insecticide again providing the maximum protection. T_8- lambda-cyhalothrin 5EC achieved the highest reduction (61.58%) (Table 4), decreasing LF damage from 2.27% to 0.69%. Although this reduction was comparatively lower than its effects on STC and LM, it remained significantly superior to botanical treatments.

Among botanical options, T_2-*A. paniculata* 5% emerged as the most effective, reducing LF damage by 47.60% (Table 4). The next best treatments were T_4-*Datura metel* (30.02%), T_5- cow urine + putrefaction mix (22.43%), T_1-*A. paniculata* 3% (19.74%), and T_6- mixed leaves decoction (16.97%). Treatments T_3 (13.37%) and T_7 (15.23%) exhibited relatively lower efficacy, indicating limited effectiveness on LF larvae.

The untreated check showed a slight natural fluctuation (2.25% to 1.78%). Across treatments, the average post-treatment LF damage (1.43%) was considerably lower than pre-treatment levels (2.34%).

Yield performance

Yield varied significantly across treatments, showing clear correspondence with the levels of pest suppression achieved. As expected, λ-cyhalothrin 5EC (T_8) produced the highest yield of 0.855 t/ha (Table 3, Figure 1), supported by its exceptional reduction of both TMB and thrips damage. This underscores the direct relationship between pest damage reduction and increased productivity.

Among botanicals, *Andrographis paniculata* decoction at 5% (T_2) recorded the highest yield of 0.803 t/ha, closely followed by Datura decoction (T_4) at 0.777 t/ha. These treatments demonstrated superior pest control efficiency among natural options, translating into better yield outcomes.

Moderate yield levels were recorded in *Calotropis* decoction (0.769 t/ha), *Andrographis* 3% (0.767 t/ha), and cow-urine-based putrefaction (0.749 t/ha). Mixed leaves decoction (T_6) and AAVYA (T_7) yielded 0.726 t/ha and 0.736 t/ha, respectively, reflecting their moderate pest suppression levels.

The untreated check (T_9) expectedly resulted in the lowest yield of 0.594 t/ha, reinforcing the substantial losses caused by uncontrolled TMB and thrips infestations. This highlights the economic importance of adopting effective pest management strategies.

Overall effectiveness and interpretation

This investigation evaluated the efficacy of eight botanical and organic treatments, along with a synthetic chemical control and an untreated check, against major cashew foliar pests: TMB, thrips, Shoot Tip Caterpillar (STC), Leaf Miner (LM), and Leaf Folder (LF). Based on a comprehensive assessment, λ-cyhalothrin 5EC (T_8) emerged as the most effective treatment in reducing pest damage and enhancing yield. However, among botanicals, *Datura metel* decoction 3% (T_4) and *Andrographis paniculata* 5% (T_2) were the top-performing alternatives, offering high reduction percentages and impressive yield gains. These botanical options can serve as sustainable, eco-friendly components in integrated pest management (IPM) programs, reducing dependence on synthetic insecticides.

Cow-urine-based fermented formulations and mixed leaf decoctions also showed promise, though their performance was slightly inferior to the best botanicals. The indigenous AAVYA product exerted moderate control and may require further refinement.

The assessment was made on the basis of pooled mean per cent pre- and post-treatment damage and the corresponding reduction percentage (R%). The results clearly indicate that all tested treatments exhibited variable degrees of efficacy across the three pest categories, with synthetic insecticide lambda-cyhalothrin 5EC (T_8) consistently outperforming the botanicals. However, certain botanical and organic formulations also showed promising suppression, emphasizing their potential as eco-friendly alternatives in Integrated Pest Management (IPM).

Comparative performance across pests

A comparison of reduction percentages across all three pests highlights that T_8- lambda-cyhalothrin - consistently recorded the highest reductions (80.19% in TMB, 90% in thrips, 71.52% in STC, 90.47% in LM, and 61.58% in LF) (Tables 2, 3), affirming its broad-spectrum efficacy. Among botanicals, two treatments stood out: *Datura metel* 3% (T_4), which achieved 67.10% reduction in TMB, 83.33% in Thrips, 37.40% in STC, 81.58% in LM, and 30.02% in LF, indicating strong performance especially against Thrips; and *A. paniculata* 5% (T_2), which achieved 62.90%

reduction in TMB, 79.07% in Thrips, 34.52% in STC, 70.93% in LM, and 47.60% in LF, demonstrating more balanced, multi-pest suppression. Cow urine + mixed leaves putrefaction (T_5) provided moderate but consistent control across all pests, suggesting its potential as a low-cost organic alternative, while other botanical combinations (T_1, T_3, T_6, T_7) exhibited lower but still meaningful suppression, indicating the presence of bioactive compounds that may function synergistically when integrated with other IPM tactics.

DISCUSSION

The present investigation assessed the efficacy of various botanical decoctions, fermented leaf preparations, an indigenous formulation, and a synthetic pyrethroid (λ-cyhalothrin 5EC) against major pests of cashew—TMB, thrips, STC, Leaf Miner (LM), and Leaf Folder (LF). The study clearly demonstrated that both botanical and chemical treatments can substantially reduce pest damage, but their effectiveness varies widely depending on the active constituents, mode of action, and persistence. The discussion below elaborates on the relative performance of these treatments and their biological implications.

Efficacy of lambda-cyhalothrin 5EC

Lambda-cyhalothrin consistently recorded the highest reduction in damage scores for TMB, thrips, STC, LM, and LF. Its superior performance can be attributed to its rapid knockdown effect, neurotoxic action, and residual activity against a broad spectrum of sucking pests and leaf feeders. The significant increase in yield (0.855 t/ha) under this treatment reflects the direct benefits of minimizing pest-induced feeding injury. However, while effective, consistent reliance on such chemicals may trigger resistance, resurgence, and ecological imbalance, highlighting the need to integrate safer alternatives. Similarly, Sundararaju (2009) and Kar (2017) reported that Lambda-cyhalothrin 5 EC @ 0.003% showed maximum efficacy in controlling leaf and blossom webber and leaf miner of cashew, while Chethana *et al*. (2023) found that Lambda-cyhalothrin 2.5 EC @ 1 ml L^{-1} was most effective in managing the leaf miner *A. syngramma* in cashew.

Performance of botanical decoctions

Among the botanical-based treatments, *Datura metel* decoction at 3% (T_4) emerged as the most effective, recording TMB and thrips reductions of 67.10% and 83.33%, respectively. *Datura* species contain alkaloids such as atropine, hyoscyamine, and scopolamine—compounds known for their potent antifeedant, repellent, and toxic properties against insect pests (Baz *et al*., 2025). The notable reduction in pest damage and the increased yield (0.777 t/ha) further support the potential of *Datura* as a promising botanical insecticide. Its consistent efficacy across both pest species also suggests strong broad-spectrum activity. *Datura* plants are notably rich in scopolamine, which has demonstrated adverse effects on various insects, including onion thrips (Malik, 2005), aphids, grasshoppers, and ants (Kuganathan & Ganeshalingam, 2011). Leaf extracts of *Datura metel L.* have also been reported to be effective against aphids (Mateen *et al*., 2025).

Andrographis paniculata decoction 5% (T_2) was the next best botanical treatment, with substantial reductions in both pests. The dose-dependent response observed between the 3% and 5% decoction treatments indicates that higher concentrations enhance the bioactivity of andrographolide, a major diterpenoid lactone known for insecticidal and antifeedant effects (Edwin*et al.*, 2021). This antifeedent activity was also reported against Rice green leaf hopper (Widiarta *et al*., 1997) and Diamond back Moth, *Plutella xylostella* (Hermawan *et al.,* 1993; Sangavi & Edward, 2017). The increased yield associated with 5% extract (0.803 t/ha) further reinforces its utility in organic and low-input cashew management systems. Obadofin *et al*. (2018) observed a similar reduction pattern:*Datura stramonium* was found more effective than *Andrographis paniculata* when it wasused against the insect pest of cowpea (*Vigna Unguiculata* L. Walp).

Similarly, *Calotropis gigantea* (T_3) and mixed leaves decoction (T_6) produced moderate levels of pest suppression in cashew. *Calotropis* contains cardenolides and latex compounds that disrupt insect digestion and feeding, explaining the observed reductions (Wen *et al*., 2016; Nawaz *et al*., 2024). Similarly, this showed anti-feedent action when it use sole against *Spodoptera exigua* (Nilamsari *et al*., 2022) and also mixed with *Crescentia Cujete* against *Spodoptera Frugiperda* (Sulastri *et al*., 2025). However, their relatively lower efficacy suggests that concentration, extraction methods, or frequency of application may require optimisation.

Effectiveness of cow urine-based fermented preparations

The cow urine + mixed leaves putrefied extract (T_5) showed a strong reduction in both TMB (59.24%) and thrips (81.22%), likely due to the presence of bioactive

metabolites produced during fermentation. Cow urine is rich in ammonia, phenols, and volatile compounds with antimicrobial and insecticidal properties, while fermentation enhances the release of secondary metabolites from the incorporated leaves. The notable pest reduction and a resulting moderate yield (0.749 t/ha) suggest that such preparations can serve as economically viable and farmer-friendly alternatives in organic cashew farming. Reports suggested that mixing cow urine with extract of plant parts after soaking, boiling or fermenting in water proved more effective than spraying of cow urine alone (Gahukar, 2020). Recent studies have shown that a "dual-attack" approach or combining two products often results in a synergistic effect (Mardiningsih & Ma'mun, 2017).

Indigenous formulation (AAVYA)

The AAVYA formulation (T_7) showed only moderate efficacy against TMB (30.28%) and thrips (45.00%). The comparatively lower performance might be due to lower concentration of active compounds, limited residual activity, or inadequate mode of action against sucking pests. Although it contributed to some reduction in pest population, the results indicate that the formulation may require further refinement in terms of dosage, extraction protocol, or component composition to achieve higher field effectiveness. Viswakethu *et al.* (2025) recorded effective reduction against banana fruit scarring beetle, *Basilepta subcostata.*

Untreated check and pest pressure

The untreated check (T_9) exhibited consistently high post-treatment damage scores in both pests, confirming ongoing natural pest pressure during the study period. The reduced yield (0.594 t/ha) (Table 3) clearly illustrates the substantial economic loss associated with uncontrolled infestations. This validates the importance of timely and effective intervention in cashew orchards, especially during peak pest activity.

Relationship between pest reduction and yield

Across treatments, improvements in yield closely mirrored the degree of pest suppression. Treatments that significantly reduced feeding damage—such as λ-cyhalothrin, *Datura*, and *Andrographis*—resulted in higher yields (0.855, 0.777 and 0.803 t/ha, respectively) (Table 3 and Figure 2), whereas treatments with lower suppression levels corresponded to reduced productivity. This indicates that damage caused by sucking and foliage-feeder pests has a direct and quantifiable impact on cashew nut development and overall yield, similarly as reported by Naik and Chakravarthy (2013). Only the tea mosquito bug responsible to cause 30% yield loss (Devasahayam & Nair, 1986; Maruthadurai *et al*., 2012).

Using botanical-based treatments in rotation or combination with low-risk chemicals may provide sustainable long-term management of cashew insect pests. Additionally, incorporating such treatments can enhance ecological resilience, improve soil health, and support organic certification processes.

CONCLUSION

In a nutshell, this study demonstrates that *Datura metel* decoction at 3% resulted in the highest reduction of TMB, thrips, and LM by 67.10, 83.33 and 81.58% over the control. Cow urine with mixed leaves putrefaction at 3% reduced STC damage by 46.5%, while *Andrographis paniculata* decoction 5%recorded the highest reduction in LF damage by 47.6%. *Andrographis paniculata* decoction 5% also gave the highest yield (0.803t/ha), followed by *Datura metel* decoction at 3% (0.777t/ha). Hence, *Datura metel* decoction at 3% can be a sustainable option for pest management in organic cashew plantations. The findings also indicate that the synergistic effects of alkaloids were essential in reducing larval feeding and hindering pest development.

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AUTHOR CONTRIBUTION

Pankaj Bhargav: Conceptualization, investigation, original draft preparation, paper writing – review, and editing. Vikas Ramteke: Resources validation, investigation, visualization, formal analysis, paper corrections. Yaspal Singh Nirala: Data curation, statistical analysis, and tabulation. T. N. Raviprasad: Methodology, technical guidance. J. D. Adiga: Supervision, project administration. D. C. Salam: Data interpretation, review and editing, technical support. All authors have read and agreed to the published version of the manuscript.