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Exploration of the effect of botanicals on controlling tea mosquito bug (*Helopeltis antonii* Signoret) in the cashew ecosystem

S Jaya Prabhavathi[1], M Senthil Kumar[2*], C Rajababu[3], K Kalpana[4], P Senthilkumar[5], K Subrahmaniyan[6] & S R Venkatachalam[1]

[1]Tapioca and Castor Research Station, Tamil Nadu Agricultural University, Yethapur, Salem 636 119, Tamil Nadu, India

[2]Horticultural Research Station, Tamil Nadu Agricultural University, Yercaud, Salem 636 602, Tamil Nadu, India

[3]Krishi Vigyan Kendra, Tamil Nadu Agricultural University, Sirugamani, Tiruchirappalli 639 115, Tamil Nadu, India

[4]Horticultural College and Research Institute, Tamil Nadu Agricultural University, Periyakulam, Theni 625 604, Tamil Nadu, India

[5]Regional Research Station, Tamil Nadu Agricultural University, Paiyur, Krishnagiri 635 112, Tamil Nadu, India

[6]Tamil Nadu Rice Research Institute, Tamil Nadu Agricultural University, Aduthurai 612 101, Tamil Nadu, India

*Email: senthilkumar.m@tnau.ac.in

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Abstract

The tea mosquito bug (TMB) *Helopeltis antonii* Signoret poses a significant threat to cashew plantations, causing substantial damage to the trees and affecting crop productivity. Botanicals have been examined for their effectiveness against tea mosquito bugs (TMB) in cashew plantations that impose damage on cashew trees. A field experiment was conducted at the Regional Research Station, Vridhachalam, Tamil Nadu, to evaluate the effectiveness of various botanical pesticides against TMB. The study included seven treatments using different botanicals and one untreated control. Applications were made at critical growth stages, namely flushing, flowering and nut formation, at fortnightly intervals, ensuring the pest population remained below the economic threshold level (ETL). Five spray rounds were administered, with a maximum of 10 L of spray suspension applied per tree for each treatment. The results demonstrated a significant reduction in TMB incidence in plots treated with botanical pesticides. Fifteen days after the third, fourth and fifth sprays, TMB incidence was completely absent in treated plots, whereas the untreated control recorded a damage score of 3.25. Furthermore, a marked decline in fresh TMB infestations was observed within seven days following each spray application. Among the treatments, a mixture of leaf extracts from adathoda *(Adathoda vasica)*, datura (*Datura metel)*, vitex (*Vitex negundo)*, calotropis *(Calotropis gigantea*) and neem (*Azadirachta indica*) showed the highest efficacy, reducing TMB incidence to damage scales of 0.660 and 0.550. Similarly, Pongamia oil (5 % concentration) exhibited substantial effectiveness, reducing TMB incidence to scales of 0.845 and 0.645. These findings highlight the potential of botanical pesticides as eco-friendly and effective alternatives for managing TMB in cashew plantations.

Keywords

botanical pesticides; cashew; leaf extracts; spraying; tea mosquito bug

Introduction

Cashew, *Anacardium occidentale* L. (*Sapindales: Anacardiaceae*), is a vital source of revenue in India. Perennial trees are cultivated in around 32 nations worldwide, especially in tropical regions of Asia, America and Africa, wherein climatic conditions favour commercial production (1). It offers various items, including cashew nuts, apples and shell liquid, which are in significant demand in international markets. The cashew tree is native to Brazil and was brought to India by the Portuguese in the 16th century. Acknowledged initially as a contributor to soil erosion, it is now extensively cultivated in tropical regions and has adapted remarkably to current Indian conditions. India is the leading producer, processor, consumer and exporter of cashews globally (2). The yield and productivity of cashews are significantly affected by various causes, with insect infestations being a primary restriction. With the expansion of cashew cultivation and productivity, the incidence of pests has also increased rapidly. The cashew tree is vulnerable to various insect pests throughout its growth and development. About 180 insect species and non–insect pests have been identified in India, leading to substantial productivity loss (3). Significant cashew pests include apple and nut borer (*Nephopteryx* sp.), inflorescence thrips (*Scirtothrips dorsalis* Hood), in addition to stem and root borer (*Plocaederus ferrugineus* L.) and tea mosquito bug (TMB) insect (*Helopeltis antonii* Signoret) (4). A major cashew pest, the tea mosquito bug insect, damages immature nuts, inflorescences and young shoots at different phases of development, resulting in yield losses. Up to 40 % yield losses have been reported in India. According to the researchers (5-7), it is a harmful pest of cocoa, tea and neem. The sap is sucking extracted from tender shoots, leaves, flower stalks and developing nuts and apples by nymphs and adults; the damage caused by the insect's suctorial mouthparts causes the tender shoots to release sticky substances. The tissue surrounding the entry point of stylets turned to necrotized, resulting in the formation of dark or black scabs, probably attributable to the phytotoxin available in the insect's saliva injected into the plant tissue during feeding. Their eating leads to the drying of new flushes, a scorched tree appearance and the shrivelling and abortion of tender nuts (8).

In the bulk of cashew-growing regions of Goa, Kerala and Maharashtra on the west coast, as well as in Vridhachalam, Cuddalore and Pudukkottai in Tamil Nadu on the east coast, TMB prevalence is reported to be severe (9). However, because of their almost regular flush production, young trees are affected by TMB all year (10). In immature cashew plants, TMB has been consistently observed throughout the year at low population densities (11). Despite the low TMB population, considerable shoot damage was reported (12) in cashew plants during monsoon. The indiscriminate application of synthetic chemical pesticides to enhance crop and vegetable yields has negatively impacted biological and physical environments, resulting in environmental contamination and a swift increase in resistance and reappearance of insect pests and diseases (13). Damage results from the high toxicity, non-biodegradable characteristics of pesticides and residues in soil, water and especially crops that impact human health. Consequently, finding unique selective and biodegradable naturally occurring indigenous insecticides is crucial. Green pesticides and the ongoing necessity for developing novel crop protection instruments indicate that phytochemicals from diverse bioactive plant species present a promising avenue for safer agrochemicals, biodegradable and selectively toxic (14). Numerous botanical preparations have been identified as having insecticidal properties (15). The well-known contributors to disease resistance are these anti-insect substances prevalent in higher plants. Numerous chemicals extracted from plants have been examined for insecticidal properties worldwide (16), with most serving as insect-feeding deterrents (17, 18). Neem's bark, seed oil and leaves have yielded over 140 structurally complex and chemically varied compounds (19). Phytochemicals are frequently unpalatable and harmful to numerous insects. They can alter the feeding deterrent behaviour of an insect (20). Biopesticides are cost-effective, more easily biodegradable, less damaging to mammals, more selective in their action and less prone to pest resistance (21). Botanical insecticides typically exhibit selective efficacy against an incomplete range of target species and tend to decompose into non–toxic compounds during biodegradation. Combined with the ability to include plants in integrated pest management systems, this good characteristic facilitates the advance of novel, safer insect control agents (22).

Furthermore, numerous plant species, particularly those in tropical areas, may operate as plant pesticides or as sources of bioactive chemicals, as recognized (23, 24). These botanicals function by either poisoning insects via their digestive systems or repelling them through potent odours and flavours. Certain hormone-mimicking drugs disrupt life cycle stages, which are particularly effective in diminishing the lepidopteran larval complex (25).

Adhatoda vasica Nees, a member of the medicinal family *Acanthaceae*, is an evergreen shrub in Tamil Nadu, usually referred to as adhatoda or Malabur nut. Initially classified as *J. adhatoda* by Linnaeus in Species Plantarum (1753), it was reclassified as *A.vasica by Nees in* 1831, which is commonly recognized today. The Adusa leaves have been utilized in Indian medicinal practices for over 2000 years. The crop is valued for its bronchodilator alkaloids, primarily vasicine. The shrub is the origin of the medication vasaka, recognized in traditional medicinal systems for its advantageous effects, particularly in bronchitis (26). It is a perennial shrub measuring 1-3 feet–height, characterized by several elongated, opposing branches. Herbaceous stem above with woody stem below (27). The leaves are opposite, exstipulate, wide, lanceolate and acuminate. The flower possesses big white petals marked with purple at the lower tip. It possesses capsular fruits containing four seeds. Every component of the plant is utilized in herbal therapy, with the leaves recognized explicitly for their parasiticidal and insecticidal effects (28, 29, 30). Antifeedent, poisonous activity and the photosynthetic capabilities of *A. vasica* are documented (31). Vasicine, an isolated bioactive component, was identified from *A. vasica* leaves, demonstrating significant potential for treating microbial infections, oxidative stress, inflammation, diabetes and human viral infections (32).

Studies have shown that extracts derived from Datura species' flowers, roots and seeds exhibit oviposition-deterrent properties against *Plutella xylostella*. Furthermore, four plant species-*Andrographis paniculata*, *Chrysanthemum morifolium*, *Melia azedarach* and *Peganum harmala*-have demonstrated similar effects in deterring or inhibiting oviposition by adult *P. xylostella* (33, 34, 35, 36). Known for the distinctive shape of their blossoms, often called Angel's trumpet or Devil's trumpet, species in the Datura genus are characterized by their high concentrations of alkaloids. Varieties such as *Datura metel* and the type species *Datura stramonium* are noted for their potent narcotic and toxic effects on humans. Commonly referred to as Jimson, *D. stramonium* belongs to the Solanaceae family and its seeds are readily available in many regions of Ethiopia. With the increasing recognition of issues like weeds competing with crops and developing herbicide resistance, Jimson has emerged as a promising candidate for biopesticide production. The mode of action of atropine –based biopesticides is similar to that of organophosphate pesticides, positioning biopesticides as a viable and sustainable alternative to chemical pesticides (37).

Acorus calamus rhizome extracts antifeedant activities were examined contrary to *T. castaneum* (38). Antifeedant properties of alkaloid-rich -fractions extracted from *Nicotiana tabacum* leaves against *T. castaneum* larvae have been documented (39). *Vitex negundo* L. is a fragrant shrub prevalent across the majority of India. Nearly all components of this plant provide medicinal use. Multiple preparations of this plant have been documented to exhibit anti-inflammatory, anti-ulcer, larvicidal and antiasthmatic, along with several other biological capabilities (40-43). Neem products originate from the seeds of the neem tree, *Azadiracta indica*, cultivated from India to Africa. Neem products have been widely used for pest management in tropical nations for field crops and stored goods. Bio-efficacy of aqueous bioformulation (BF-I) was examined and cow urine–based bioformulation (BF-II) against grey mould in strawberries, concluding that BF-II was more efficient (44) in inhibiting mycelial growth (95.4 %) than BF-I (82.0 %). BF-II produced an 85.9 % decrease in the occurrence of grey mould and an 81.4 % increase in yield relative to the untreated control.

The Vitex genus comprises approximately 250 species of shrubs and trees, characterized by a substantial amount of ecdysteroids and terpenes, the latter being natural hormones involved in biochemical processes in insects (45). *Vitex negundo* L., commonly known as Sambhaloo and belonging to the Verbenaceae family, is characterized by its slender grey bark. Widely accessible, this herb is renowned for its therapeutic properties and effectiveness against numerous ailments within traditional medicine practices. (46). Numerous secondary metabolites, including alkaloids, phenols, flavonoids, glycosidic iridoids, tannins and terpenes, are present in all plant sections, particularly in the leaves (47). Hepatoprotective, anti-inflammatory, antitumour, antioxidant, insecticidal, anti–hyperglycemic, antiandrogenic, anti–cataract, anti-osteoporotic, as well as antimicrobial activity were among promising bioactivities that crude extracts along with *Vitex negundo* purified components displayed (48). Erukku, or Milkweed plant (*Calotropis gigantea* R. Br.), Asclepiadaceae family member, is a prevalent weed reported in wastelands in Asian tropical & subtropical regions (49). In addition to its several medical and industrial applications, it has garnered increased attention recently as a possible pesticide agent against insect pests (50). It is recognized for its insecticidal, antibacterial, & antifungal activities (51, 52). Plant extract demonstrated efficacy against lepidopteran and sap-sucking pests of several crops (53, 54). Milkweed plant extracts, which include insecticidal compounds, including glycosides or flavonoids, are readily degradable in agricultural ecosystems and are efficient against several insect pests (55, 56).

Citrus fruits are rich in flavonoids and, combined with other secondary metabolites, significantly reduce reactive oxygen species, decreasing cancer risk. Recent studies indicate that *C. maxima* peel extracts and NAR exhibit significant anticancer efficacy against MCF-7 breast cancer cells. Moreover, results demonstrate a substantial inhibition of breast cancer cell motility and colony formation by these extracts and NAR. Due to this unique action method, *C. maxima* peel extracts, NAR presents potential as an effective breast cancer treatment. Common herbal pesticidal crops available in Tamil Nadu, India, are commonly used in organic pest management. The scientific names follow the common names. They are Devils Trumpet, *Datura metel*; Notchi, *Vitex nugunda*; Pungam, *Pongamia glabra*; Neem, *Azadirachta indica*; Erruku, *Calatropis gigantea*; Tobacco, *Nicotiana tobaccum*; Chevanthi, *Chrysanthemum cinerrifolia* (57).

Numerous synthetic chemical pesticides have been employed in crops to manage insect pests. Accumulating synthetic insecticides in the environment, resulting in harmful residues, has caused multiple problems, including pest resistance, the development of new pest species and contamination of the agroecosystem, air, water and soil. (58). Biopesticides are regarded as environmentally safe, selective, biodegradable, cost-effective, & renewable choices for implementation in Integrated Pest Management programs. Biopesticides are classified as secondary metabolites and encompass alkaloids, terpenoids, phenolics and other small secondary compounds. Various plant species from distinct families and genera have been documented to possess poisonous compounds that are efficient against insects (59). The encounters of pesticide resistance and pest reappearance, coupled with rising insecticide residues on crops, have necessitated the urgent development of more sustainable management measures for the tea mosquito bug in cashew plantations (60).

Numerous botanical formulations have demonstrated efficacy comparable to standard synthetic pesticides, even at low dosages for forty years. Plant-based pesticides have attracted significant interest in organic agriculture as primary control agents. Secondary metabolites that are physiologically active are abundant in higher plants. Higher plants are the source of nearly eighty per cent of all identified phenols alkaloids, among other secondary metabolites. The spraying of plant extracts to control dangerous insects is not novel; pyrethrin, rotenone and nicotine have long been employed in commercial and small–scale subsistence farming (61). Pest management with botanical insecticides has been advocated as a substitute for synthetic chemicals. The use of botanical insecticides has emerged as a promising and eco–friendly alternative to synthetic chemical pesticides. These plant-derived products, known for their bioactive compounds, are considered safer for non-target organisms and the environment. In light of the need for sustainable pest management strategies, this study aims to evaluate the effectiveness of various indigenous plant extracts with biopesticidal properties in controlling the tea mosquito bug (*Helopeltis* spp.) in cashew orchards. The research seeks to highlight the potential of botanicals as a key component in integrated pest management (IPM) for cashew cultivation.

Considering all these factors, the present investigation aimed to find Indigenous plant extracts with biopesticide capabilities for evaluating the worth of botanicals in managing the tea mosquito bug in cashew orchards.

Materials and Methods

The leaves, flowers and seeds were obtained from the nearby farm areas of the local places of the Regional Research Station, Vridhachalam, Cuddalore District, Tamil Nadu, India. Plant parts were cleaned and dried at room temperature in the shade (Fig. 1).

Field experiments have been performed from 2019-20 in cashew plantations with the experimental area of one acre at the Regional Research Station in Vridhachalam under the All India Coordinated Research Project on Cashew (AICRP-Cashew), utilizing randomized block design with four replications along with eight treatments on 10-year-old VRI 3 variety plants. TheVRI-3 cashew variety developed by the Regional Research Station, TNAU, Vridhachalam, was

Fig. 1. Botanicals used for this experiment.

used for the study because of the popularity of the variety VRI–3 among Tamil Nadu farmers as well as in Karnataka, Kerala, Andhra Pradesh and Maharashtra states for its export-grade bold nut kernels, Compact canopy, early flowering, easy peeling of testa and amenable to pruning and are also suitable for the high-density planting system. Treatments included were mentioned hereunder.

Treatment details and botanicals preparation methodology

T_1- Leaves of each of 500g of Adathoda, Datura, Vitex, Calotropis and Neem were ground and the resulting leaf extracts were immersed in 10L of water and fermented at pH ranging from 5.5 to 6.5 for 15-20 days and the supernatant subsequently utilized for spraying; T_2- Neem Seed Kernal Extract (NSKE) 5 % was prepared and used; T_3- Seeds of Nerium, pongam, tobacco waste and pods of datura (Each 500 g), Lime - 250 g, Cow urine - 5 L, Soaked in mud pot with 10 L of water for seven days and the supernatant was used for spraying; T_4– Rhizomes of Acorus 5 % soaked overnight and the supernatant was used for spraying; T_5- pongam oil 5 %; T_6-Citrus peel extract and leaf extracts of tulsi, custard apple and chrysanthemum flowers (Each 250 g), Lime - 250 g, Cow urine - 5 L. Soaked in Mud pot with 10L of water for seven days; T_7 - Standard treated check (Spraying of lambda-cyhalothrin 5 % EC @ 0.6 mL/L of water); For all the treatments, khadhi soap at a concentration of 1g/L of water has been utilized for spraying.T8-Untreated check.

Botanical pesticides were applied in the flushing, flowering and fruit formation stages at fortnight intervals before reaching ETL. Five sprays were administered, with a maximum of 10L spray suspension applied per tree for each treatment. 2 trees in each treatment were separated from the adjoining set of treatment trees by at least 1 row of guard trees. These guard trees should also be sprayed with the same botanicals for respective botanical pesticide treatments.

Observations recorded

Pest incidence data for every treatment was obtained from 52 freshly chosen tree leader shoots of each tree at the canopy's north, west, east and south sides. These shoots were labelled individually and pest infestation was recorded on 7 and 15 days after each spray. TMB infestation (damage on a 0-4 scale) on flushes and population of TMB (adults and nymphs) were noted. Pre-treatment observations were reported one day before each spray and post-treatment observations were documented 15 days following each spray. As indicated below, the number and type of necrotic lesions were used to score the degree of damage (Table 1.) to shoots and panicles on a 0-4 scale (62).

The Equation 1 formula below converted recorded data to the percentage incidence of cashew tea mosquito bugs.

$$\text{Per cent incidence} = \frac{\text{Sum of numerical rating}}{\text{No. of shoots observed} \times \text{maximum rating}} \times 100 \quad \text{(Eqn.1)}$$

Table 1. Damage scoring method for TMB in cashew

Scale	Description of damage symptoms
0	No lesion /streak
1	Up to 3 necrotic lesions/streaks
2	4-6 coalescing or non- coalescing lesion/streak
3	Above 6 coalescing or non- coalescing lesions
4	Lesions/streak confluent - complete drying of affected shoot/panicle

Evaluation of phytotoxicity of botanicals on cashew

Affording to the C.I.B. & R.C (Central Insecticide Board & Registration Committee's) protocol, wilting, leaf damage, necrosis, epinasty, vein clearing, as well as hyponasty were all seen in each tree at 1, 3, 5, 7, 10 and 14 days following spraying in botanical field experiments.

Method of assessment of phytotoxicity

Leaf injury was evaluated by visual rating on a 0-10 scale

Rating	Phytotoxicity (%)
0	No phytotoxicity
1	0 to 10
2	11 to 20
3	21 to 30
4	31 to 40
5	41 to 50
6	51 to 60
7	61 to 70
8	71 to 80
9	81 to 90
10	91 to 100

The percent leaf injury was evaluated employing the Equation 2 formula,

$$\text{\% leaf injury} = \frac{\text{Total grade points}}{\text{Maximum grade} \times \text{number of leaves observed}} \times 100 \quad \text{(Eqn.2)}$$

Observation on yield

The nut yield from each tree was recorded separately for all the individual treatments. The total yield for each treatment was calculated by adding the yields from successive harvestings by collecting cashew nuts. Then, the cashew apple was detached from the nuts and the nuts were weighed for yield calculation. This total yield per tree was calculated to kg per tree.

Statistical analysis

One day before each spray, observations were recorded before treatment, while post-treatment observations were taken 7 and 15 days after each. The collected data were subjected to ANOVA, with necessary transformations applied to enable comparisons of treatment means (63). The STAR IRRI package, developed by the International Rice Research Institute in the Philippines, was used to analyze yield performance across treatments. Variations among treatment means were assessed using Critical Difference (CD) at a 5 % significance level, along with P-values. Economic analysis of the collected data was performed following standard methodologies established by CIMMYT, Mexico.

Results

Effect of botanicals against TMB incidence and population

According to the results of the botanical pesticide against TMB, the effectiveness of the botanicals was not as high as standard insecticides treated 15 days after the third, fourth and fifth. Before arriving at ETL, all plant-based pesticides were sprayed in the field. The first and second sprays were completed during the flushing period before TMB incidence. In contrast to the untreated check (the damage score observed was 2.5), TMB incidence was not seen in botanical pesticides sprayed trees. TMB's pre-treatment damage score was not statistically significant in all treatments, excluding untreated checks. Seven days following each spraying session, a decrease in new infestation was noted. TMB incidence can be effectively controlled with a standard insecticide check (Spraying of lambda-cyhalothrin 5 % EC at 0.6 mL/L of water). Spraying a combination of leaf extracts from adathoda, calotropis, datura, vitex and neem was the most effective way to control TMB incidence (0.175 & 0.124 scale) (Table 2). This was followed by 5 % Pongam oil (0.225 and 0.150 scale), 5 % rhizomes of Acorus (0.463 and 0.363 scale) and 5 % NSKE (0.625 and 0.550 scale of TMB). The same was noticed in 7 DAS and 15 DAS of the 4th and 5th sprayings. In contrast to the untreated control's enhanced damage score of 3.725, the damage scores after the fourth spray varied between 0.003 and 0.764 in various treatments. Damage scores decreased 15 days after the fifth spray and ranged from 0.0016 to 0.6385 for different treatments, compared to an improved score of 3.825 for the control group (Table 3.).

Overall efficacy has been given in order against TMB incidence along with Vridhachalam population are given below: T_9-Standard treated check (Spraying of lambda cyhalothrin 5 % EC at 0.6mL/L of water)>T1-spraying of combined leaf extracts of adathoda, calotropis, vitex, datura and neem>T_6-5 % pongam oil>T_5-5 % Rhizomes of acorus >T_2-5 % NSKE>T_4-pongam, tobacco waste, Nerium, as well as pods of datura (500 g each), Lime-250 g, Cow urine -5 L >T_7-Extract of citrus peel and tulsi, custard apple as well as chrysanthemum flowers (250g each), Lime -250 g, Cow urine-5 L. It is evident from the results of findings of the antifeeding effect of thirteen different plant extracts against third instar, 24 hr. starved *Spilarctia obliqua* larvae under laboratory trial that *Adhatoda vasica* Linn. and *Cleoma monophylla* Linn. had promising protective power than the other plant origin insecticide (16).

Table 2. Effect of botanicals on the incidence of TMB at Vridhachalam

Code	Treatment	Pre-treatment damage score (0-4)	Post treatment mean damage score (0-4) III Spray		Pre-treatment damage score (0-4)	Post treatment mean damage score (0-4) IV Spray		Pre-treatment damage score (0-4)	Post treatment mean damage score (0-4) V Spray	
			7 DAS	15 DAS		7 DAS	15 DAS		7 DAS	15 DAS
T_1	Leaf extracts of each of 500 g of adathoda, datura, vitex, calotropis and neem fermented for 15-20 days and soaked in mud pot with 10 L of water.	1.703 (1.644)	0.175 (1.084)	0.124 (1.060)	3.598 (2.144)	0.007 (1.004)	0.007 (1.004)	3.550 (2.133)	0.007 (1.004)	0.0054 (1.003)
T_2	NSKE 5 %	1.650 (1.627)	0.625 (1.275)	0.550 (1.245)	3.553 (2.134)	0.550 (1.245)	0.525 (1.235)	3.625 (2.150)	0.525 (1.235)	0.4750 (1.214)
T_3	Seeds of Nerium, pongam, tobacco waste and datura pods (Each 500 g), Lime- 250 g, Cow urine- 5 L. Soaked in a mud pot with 10 L of water for seven days.	1.600 (1.612)	0.875 (1.369)	0.775 (1.332)	3.525 (2.127)	0.814 (1.346)	0.764 (1.327)	3.550 (2.132)	0.789 (1.337)	0.6385 (1.277)
T_4	Rhizomes of Acorus 5 % soaked overnight.	1.500 (1.581)	0.463 (1.209)	0.363 (1.167)	3.425 (2.103)	0.418 (1.191)	0.393 (1.180)	3.575 (2.139)	0.443 (1.201)	0.3933 (1.180)
T_5	Pongam oil 5 %	1.525 (1.589)	0.225 (1.107)	0.150 (1.072)	3.505 (2.122)	0.114 (1.055)	0.089 (1.044)	3.500 (2.121)	0.105 (1.051)	0.0803 (1.039)
T_6	Citrus peel extract and leaf extracts of tulsi, custard apple and chrysanthemum flowers (Each 250 g), Lime- 250 g, Cow urine- 5 L. Soaked in mud pot with 10 L of water for seven days.	1.550 (1.596)	0.350 (1.162)	0.725 (1.313)	3.523 (2.127)	0.683 (1.296)	0.658 (1.286)	3.500 (2.121)	0.658 (1.287)	0.5830 (1.255)
T_7	Standard treated check (Spraying of lambda-cyhalothrin 5 % EC @ 0.6 mL/ L of water)	1.325 (1.524)	0.010 (1.005)	0.005 (1.003)	3.548 (2.132)	0.004 (1.002)	0.003 (1.002)	3.525 (2.127)	0.002 (1.001)	0.0016 (1.001)
T_8	Untreated check	3.250 (2.061)	3.550 (2.133)	3.600 (2.145)	3.600 (2.145)	3.650 (2.156)	3.725 (2.174)	3.775 (2.185)	3.800 (2.191)	3.8250 (2.197)
	C.D.	NS	0.031	0.032	NS	0.044	0.044	NS	0.045	0.078
	SE(m)	0.023	0.01	0.011	0.014	0.015	0.015	0.020	0.015	0.026
	SE(d)	0.032	0.015	0.016	0.02	0.021	0.021	0.027	0.022	0.037
	C.V.	2.741	1.594	1.738	1.306	2.398	2.411	1.842	2.373	4.121

Mean of four replications; DAS – Days After Spraying; Values in the parentheses are $\sqrt{x+0.5}$ transformed values

Table 3. Efficacy of botanicals on TMB population /52 leader shoots at Vridhachalam

Code	Treatment	Pre-Treatment Count /52 leader shoots	Post-treatment count (Mean TMB population/52 leader shoots) III Spray 7 DAS	Post-treatment count (Mean TMB population/52 leader shoots) III Spray 15 DAS	Pre-Treatment Count /52 leader shoots	Post–treatment count (Mean TMB population/52 leader shoots) IV Spray 7 DAS	Post–treatment count (Mean TMB population/52 leader shoots) IV Spray 15 DAS	Pre-Treatment Count /52 leader shoots	Post-treatment count (Mean TMB population/52 leader shoots)) V Spray 7 DAS	Post-treatment count (Mean TMB population/52 leader shoots)) V Spray 15 DAS
T_1	Leaf extracts of each of 500 g of adathoda, datura, vitex, calotropis and neem fermented for 15-20 days and soaked in mud pot with 10 L of water.	1.680 (1.637)	0.237 (1.111)	0.187 (1.089)	2.448 (1.856)	0.335 (1.060)	0.285 (1.133)	2.706 (1.925)	0.235 (1.111)	0.123 (1.060)
T_2	NSKE 5 %	1.800 (1.673)	0.822 (1.35)	0.722 (1.312)	2.325 (1.823)	1.148 (1.242)	1.098 (1.448)	2.750 (1.936)	1.048 (1.431)	0.543 (1.242)
T_3	Seeds of Nerium, pongam, tobacco waste and datura pods (Each 500 g), Lime- 250 g, Cow urine-5 L. Soaked in a mud pot with 10 L of water for seven days.	1.750 (1.658)	0.865 (1.366)	0.765 (1.328)	2.285 (1.812)	1.430 (1.404)	1.355 (1.534)	2.529 (1.879)	1.305 (1.518)	0.971 (1.404)
T_4	Rhizomes of Acorus 5 % soaked overnight.	1.703 (1.644)	0.779 (1.333)	0.679 (1.295)	2.273 (1.809)	0.958 (1.202)	0.908 (1.381)	2.700 (1.923)	0.858 (1.363)	0.446 (1.202)
T_5	Pongam oil 5 %	1.725 (1.651)	0.555 (1.247)	0.505 (1.226)	2.308 (1.818)	0.455 (1.095)	0.405 (1.185)	2.805 (1.950)	0.355 (1.164)	0.199 (1.095)
T_6	Citrus peel extract and leaf extracts of tulsi, custard apple and chrysanthemum flowers (Each 250 g), Lime– 250 g, Cow urine– 5 L. Soaked in mud pot with 10 L of water for seven days.	1.675 (1.635)	0.925 (1.387)	0.706 (1.302)	2.343 (1.828)	1.796 (1.354)	1.746 (1.657)	2.699 (1.923)	1.671 (1.634)	0.834 (1.354)
T_7	Standard check (Spraying of lambda-cyhalothrin 5 % EC @ 0.6 mL/ L of water)	1.698 (1.642)	0.036 (1.018)	0.026 (1.013)	2.295 (1.815)	0.141 (1.002)	0.091 (1.044)	2.652 (1.911)	0.041 (1.02)	0.004 (1.002)
T_8	Untreated check	1.800 (1.673)	1.950 (1.717)	2.575 (1.889)	2.550 (1.884)	3.300 (2.179)	3.550 (2.133)	3.550 (2.133)	3.675 (2.162)	3.750 (2.179)
	C.D.	N/A	0.054	0.095	N/A	0.02	0.036	0.032	0.03	0.018
	SE(m)	0.014	0.018	0.032	0.023	0.007	0.012	0.011	0.01	0.006
	SE(d)	0.019	0.026	0.045	0.033	0.009	0.017	0.015	0.014	0.009
	C.V.	1.649	2.75	4.915	2.513	1.002	1.691	1.11	1.422	0.920

Mean of four replications; DAS – Days After Spraying; Values in the parentheses are $\sqrt{x+0.5}$ transformed values

Effect of botanicals against per cent incidence of TMB and yield

Table 4. depicted the results and among the botanicals tested for their efficacy against tea mosquito bug, the per cent incidence of the pest was very low in the sprayed trees of cashew with the leaf extracts from Adathoda, calotropis, datura and vitex, as well as neem and was the most effective way to control TMB incidence (0.225) which possess several secondary metabolites which lead to reduced pest incidence and recorded higher cashew nut yield (6.450 kg/ tree) when it was compared to untreated check it was high per cent incidence (4.210 per cent damage) and low Cashew nut yield (4.550 kg/tree). This was followed by 5 % pongam oil and 5 % rhizomes of acorus.

Phytotoxic effect of botanicals on cashew

In cashew variety VRI-3, findings of studies on phytotoxic effects of botanicals sprayed every 2 weeks during flushing, flowering and fruit formation stages are provided in Table 5. No phytotoxic symptoms, including damage to the leaf tip and leaf surface, vein clearing, wilting, epinasty, necrosis, or hyponasty, had been observed in any botanical treatments. Plant-based pest control agents have long been promoted as alternatives to synthetic chemicals for integrated pest management. These phytochemicals are believed to have minimal environmental and human health impact (64). Therefore, the conclusion was that these botanical treatments did not damage cashews.

Discussion

In the field experiment, the combined application of leaf extracts from Adathoda, Calotropis, Vitex, Datura and Neem proved effective botanical pesticides for managing the population and incidence of the tea mosquito bug. These findings align with other studies demonstrating plant–based products' efficacy in controlling pathogens and insect pests. For instance, aqueous extracts from citrus (*Citrus cinensis*), cocoa (*Theobroma cacao*), cashew (*Anacardium occidentale*) and Mexican sunflower (*Tithonia diversifolia*) have been reported to effectively manage the population of *Macrotermes bellicosus* in field conditions (65). Leaf extracts of *Justicia adhatoda* have shown significant activity against diverse clinical pathogens and exhibited more substantial antimicrobial effects on bacterial strains than fungal ones (30). The leaves of *Adathoda vasica*, which contain alkaloids such as Adhatodine, Vasicinone and Vasicine, have been found to exhibit toxic effects (66). Furthermore, the 80 % crude leaf extracts of *Adatoda vasica* Nees, prepared with acetone and methanol, demonstrated insecticidal properties by causing mortality in both nymphs and adults of *Brevicoryne brassicae*, making them suitable for use as

Table 4. TMB damage per cent incidence and the yield on the effect of botanicals in cashew plantations

	Treatment	Mean Damage % incidence after 5th spray TMB		Yield (kg per tree)
		PTC	15 DAS	
T_1	Leaf extracts of each of 500 g of adathoda, datura, vitex, calotropis and neem fermented for 15-20 days and soaked in mud pot with 10 L of water.	3.750 (11.159)	0.225 (2.706)	6.450
T_2	NSKE 5 %	3.750 (11.159)	0.750 (4.963)	5.925
T_3	Seeds of Nerium, pongam, tobacco waste and datura pods (Each 500 g), Lime- 250 g, Cow urine- 5 L. Soaked in a mud pot with 10 L of water for seven days.	3.750 (11.160)	0.863 (5.325)	5.825
T_4	Rhizomes of Acorus 5 % soaked overnight.	3.775 (11.192)	0.688 (4.748)	5.513
T_5	Pongam oil 5 %	3.725 (11.122)	0.475 (3.936)	5.575
T_6	Citrus peel extract and leaf extracts of tulsi, custard apple and chrysanthemum flowers (Each 250 g), Lime- 250 g, Cow urine- 5 L. Soaked in mud pot with 10 L of water for seven days.	3.725 (11.121)	1.238 (6.373)	5.750
T_7	Standard treated check (Spraying of lambda-cyhalothrin 5 % EC @ 0.6 mL/L of water)	3.800 (11.235)	0.005 (0.413)	6.725
T_8	Untreated check	3.910 (11.400)	4.210 (11.835)	4.550
	C.D.	NS	0.367	0.026
	SE(m)	0.126	0.126	0.009
	SE(d)	0.179	0.178	0.012
	C.V.	2.265	5.030	0.669

Mean of four replications; PTC– Pre Treatment Count; DAS: Days After Spraying; Values in the parentheses are arc sine $\sqrt{\text{per cent}}$ transformed values for per cent damage and $\sqrt{x+0.5}$ transformed values for population numbers.

Table 5. Phytotoxic effect of botanicals on cashew ecosystem

Code	Treatments	Phytotoxicity rating*				
		Injury to leaf tip and leaf surface	Wilting	Vein clearing	Necrosis	Epinasty and Hyponasty
T_1	Leaf extracts of each of 500 g of adathoda, datura, vitex, calotropis and neem fermented for 15-20 days and soaked in mud pot with 10 L of water.	0	0	0	0	0
T_2	NSKE 5 %	0	0	0	0	0
T_3	Seeds of Nerium, pongam, tobacco waste and datura pods (Each 500 g), Lime- 250 g, Cow urine - 5 L. Soaked in a mud pot with 10 L of water for seven days.	0	0	0	0	0
T_4	Rhizomes of Acorus 5 % soaked overnight.	0	0	0	0	0
T_5	Pongam oil 5 %	0	0	0	0	0
T_6	Citrus peel extract and leaf extracts of tulsi, custard apple and chrysanthemum flowers (Each 250 g), Lime- 250 g, Cow urine- 5 L. Soaked in mud pot with 10 L of water for seven days.	0	0	0	0	0
T_7	Standard treated check (Spraying of lambda-cyhalothrin 5 % EC @ 0.6 mL/L of water)	0	0	0	0	0
T_8	Untreated check	0	0	0	0	0

Mean of four observations; *Observed on 1, 3, 5, 7, 10 and 15 days after first, second, third, fourth and fifth spraying.

insecticides (67). Similarly, dust formulations derived from various parts of the milkweed plant (*Calotropis gigantea* R. Br.), including flowers, leaves, roots and stems, exhibited insecticidal activity against *Helicoverpa armigera* (Hubner) (56). *C. procera* is recognized for containing chemical compounds, including Calotropin and Calotoxin, which have been shown to possess insecticidal properties (68). The limonoids present in the neem leaf extracts, such as Azadiron, Amoorastatin, Vipinin, Vilasinin, Gedunin, Nimbin, Nimbolinin and Salannin lead to reduced pest activity (69). Chemical compounds extracted from *V. negundo* using petroleum ether and methanol likely interfere with the feeding behaviour of the insect. These chemicals are believed to be detected through receptors such as sensilla on the antennae, labrum, maxillary and labial palps of *T. Castaneum* (43). The GC-MS analysis of ethanol extracts from Datura leaves identified 14 compounds, with 1-Butanol, 3-methyl being the primary component (79.76 %), followed by Toluene (6.14 %) and Phytol (3.9 %). In contrast, the GC-MS analysis of the flowers also detected 14 compounds, with formic acid, 3-methyl but-2-yl ester being the dominant compound (82.22 %), followed by Dodecanoic acid, ethyl ester (3.3 %) and Toluene (2.86 %). Other compounds included Methyl-oxiran-2-yl-methanol (2.1 %) and Carbamic acid, 2-(2-tolyloxycarbonylamino) (2.04 %) (70).

Conclusion

The present study verified the insecticidal properties of Adathoda, Datura, Vitex, Calotropis and Neem leaf extracts. Environmental pollution and health risks from pesticide residues in food and fibre remain significant concerns. However, biopesticides offer a sustainable alternative, as they are generally less harmful than chemical insecticides. Unlike broad-spectrum chemical pesticides, which may harm beneficial insects, birds, mammals, or other non-target species, biopesticides typically target specific pests or closely related groups. They are effective in smaller quantities, decompose rapidly and do not contribute to environmental pollution. Additionally, biopesticides are often more cost-effective than chemical alternatives and did not cause phytotoxic symptoms in this study.

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Authors' contributions

SJP carried out the experiment, took observations and analyzed the data. MSK helped me write an original draft, analyze data and summarize it. CR helped write reviews and summarize and KK reviewed the manuscript and helped edit and summarise it. PS reviewed the manuscript and supervised the designing of study protocols. KS contributed by developing the ideas, supervising the experiment and coordinating the manuscript. SRV helped summarize and revise the manuscript. All the authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

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