PLANT SCIENCE TODAY
ISSN 2348-1900 (online)
Vol x(x): xx–xx
https://doi.org/10.14719/pst.7327

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REVIEW ARTICLE

Tea mosquito bug, *Helopeltis* spp. (Miridae; Hemiptera) an emerging phytotoxic pest: A comprehensive review of its biology and management

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OPEN ACCESS

ARTICLE HISTORY
Received: 20 January 2025
Accepted: 29 January 2025
Available online
Version 1.0 : 28 February 2025

Check for updates

Additional information

Peer review: Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

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Indexing: Plant Science Today, published by Horizon e-Publishing Group, is covered by Scopus, Web of Science, BIOSIS Previews, Clarivate Analytics, NAAS, UGC Care, etc
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CITE THIS ARTICLE
Jaya Prabhavathi S, Kavimugilan S, Kalyanasundaram A, Gowsalya R, Nanthini B, Natarajan SK, Elankavi S, Venkatachalam SR. Tea mosquito bug, *Helopeltis* spp. (Miridae; Hemiptera) an emerging phytotoxic pest: A comprehensive review of its biology and management. Plant Science Today (Early Access). https://doi.org/10.14719/pst.7327

Abstract

The Tea Mosquito Bug (TMB), *Helopeltis* spp. (Miridae: Hemiptera), is a highly destructive pest that significantly threatens plantation and fruit crops across tropical and subtropical regions worldwide. With a wide host range, *Helopeltis* spp. infests various economically vital crops such as tea, cashew, pomegranate, guava, neem and cocoa. Both nymphs and adults feed by piercing plant tissues, extracting fluids and injecting enzymes like polyphenol oxidase from their salivary glands, leading to browning and scab-like lesions on affected plant parts, ultimately reducing yield. Additionally, the damage is compounded by the transmission of secondary pathogens, particularly *Botryodiplodia theobromae* and *Phytophthora*, causes which lead to dieback diseases in crops like neem and pomegranate, resulting in causing considerable economic losses. Although chemical control methods especially insecticides have traditionally been used for managing *Helopeltis* spp., excessive reliance on these methods has led to various challenges. These include the development of pesticide resistance, environmental pollution and concerns about pesticide residues in agricultural products resulting in strict regulations in many developed nations. As a result, there is a pressing need for alternative and sustainable management strategies. Integrated Pest Management (IPM), which incorporates biological control agents, cultural practices, botanical insecticides and selective chemical use has emerged as a promising and environmentally sound approach for controlling *Helopeltis* spp. in an economically viable way. This review provides an in-depth assessment of the biology, ecology and behavior of *Helopeltis* spp., along with a comprehensive analysis of their global host plant range. Furthermore, it highlights recent advancements in pest management, particularly focusing on IPM strategies and ongoing research into biological control, such as utilizing natural predators and parasitoids. By reducing dependency on chemical pesticides, these sustainable practices are crucial for minimizing the impact of TMB on global agricultural systems enhancing crop resilience and promoting long-term environmental sustainability.

Keywords

Helopeltis; phytotoxima; sap sucking; tea mosquito bug

Introduction

The tea mosquito bug (Hemiptera: Miridae) is a destructive pest with a significant global impact on plantations and fruit crops. Three primary species *Helopeltis theivora* (Waterhouse), *H. bradyi* (Waterhouse) and *H. antonii* (Signoret) are of particular concern. In India, these species are well documented, with *H. antonii* being the most dominant (1-3) species, particularly on cashew, due to its widespread distribution, high population density and significant economic impact as a pest. The pest has been reported to infest 17 plant species across 13 families, including economically important crops such as plantation crops *viz.*, cashew, tea, coffee; vegetable crops *viz.*, eggplant, amaranthus; pulse crop such as redgram; fruit crops *viz.*, guava, grapes, pomegranate, mango, apple, *Annona* spp., avocado, rose apple, almond; spice crops *viz.*, black pepper, allspice, cinchona, annatto, camphor, tamarind; tree crops neem, *Eucalyptus* spp. and fibre crop such as cotton (Table 1). The feeding activity of both nymphs and adults involves piercing plant tissues and sucking sap while injecting enzymes such as polyphenol oxidase from their salivary glands, leading to desiccation of young shoots and a characteristic scorched or burnt appearance (4, 5). Additionally, the tea mosquito bug is associated with dieback pathogens, including *Botryodiplodia theobromae* in cashew and pomegranate (6) and *Phytophthora* in neem (7). These pathogen-pest interactions exacerbate crop damage, resulting in substantial yield losses. For example, cashew yield losses range from 30 % to 50 % (8), tree drying ranges from 50 % to 80 % (7) and guava fruit losses have been reported as high as 60 % to 70 % (9). The pest population shows a seasonal trend, beginning to increase in October or November, peaking between December and March, particularly in January when trees are in full bloom and declining sharply after May due to the monsoon (10). Current management practices for *H. antonii* on cashew rely heavily on chemical control (11). However, concerns over pesticide residues in cashew kernels, particularly in export markets, necessitate the development of integrated pest management (IPM) approaches. These approaches should prioritize non-chemical methods to effectively mitigate pest damage while adhering to international food safety standards. This review aims to comprehensively explore the biology, host plants and management strategies for the tea mosquito bug, with an emphasis on sustainable and globally applicable control measures.

Host range and Distribution

TMB targets a variety of economically important plants, including tea, coffee, cocoa and various fruit and ornamental species. Understanding the host range of *Helopeltis* is crucial for effective pest management strategies, as it enables farmers and agriculturalists to identify vulnerable crops and implement preventative measures. Nine species of *Helopeltis* could be found in Indonesia (2). These species include *H. antonii, H. chinconae, H. bradyi, H. cuneata, H. fasciaticollis, H. insularis, H. sulawesi, H. sumatranus* and *H. theivora* (Fig. 1). *H. antonii* is found only in South and East India, the Andaman Islands and Sri Lanka, whereas *H. bradyi* is restricted to South India, Sri Lanka, Indonesia and Malaysia (3).

H. theivora is distributed across South India, Northeast India, Sri Lanka and Southeast Asia. In India, three species of *Helopeltis*: *H. antonii*, *H. bradyi* and *H. theivora* have been recorded, with *H. antonii* being the dominant species (12). *H. cinchonae* is active year-round in Malaysia. The biological attributes of this species, including its oviposition choices on different host plants, are largely consistent with those observed in Malaysia (13). Description of the *Helopeltis* species is given (Table 2). [Insert Table 1, 2 here]

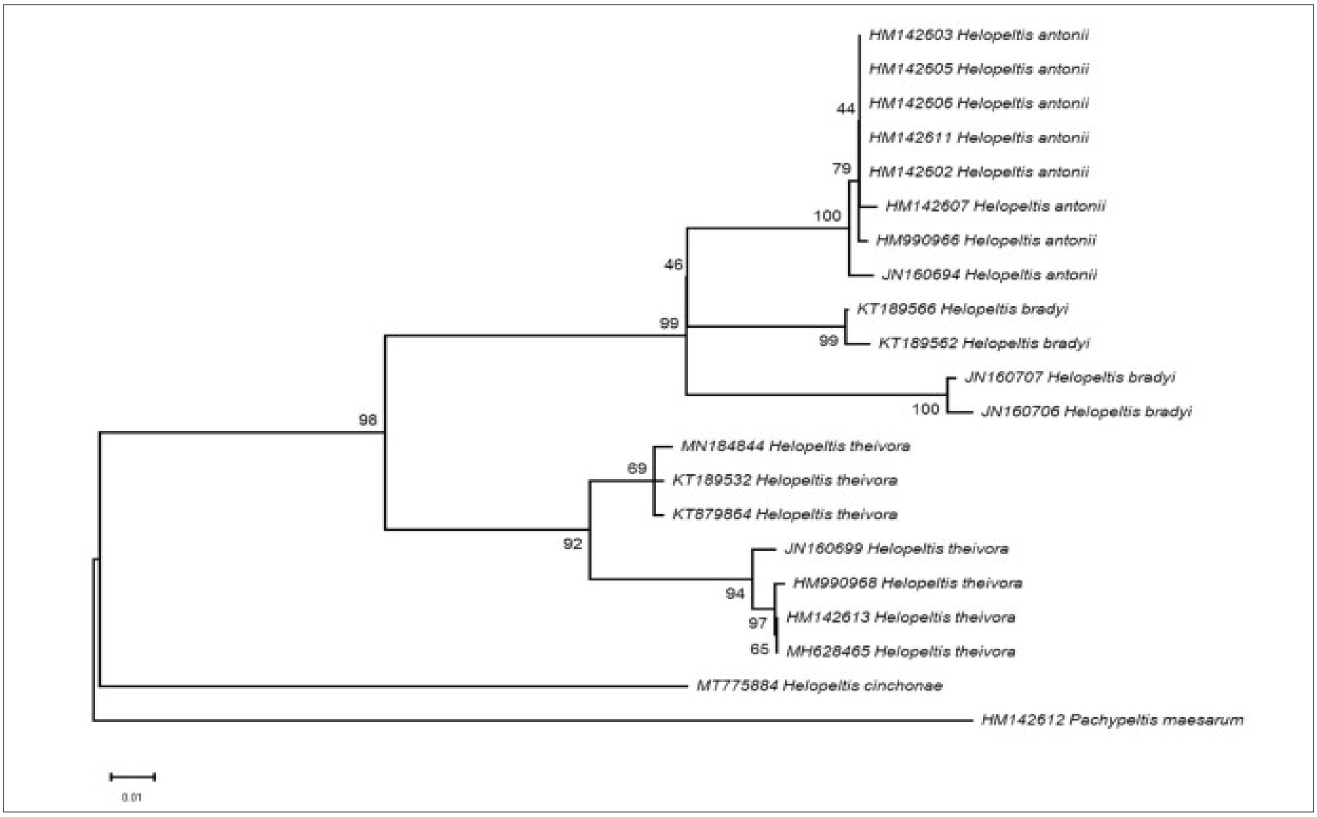

Fig. 1. Maximum Liklihood (ML) tree based on partial COI sequence (560 bp) of *Helopeltis cinchonae, H. antonii, H. bradyi* and *H. theivora* (15).

Table 1. Host Plants of *Helopeltis* species

S. No.	Host	Botanical Name	Reference
		A. Helopeltis antonii	
1	Achiote	*Bixa orellana* L.	(16)
2	Red cinchona	*Cinchona pubescens* L.	(16)
3	Chinaberry	*Melia azedarach*	(16)
4	American mahogany	*Swietenia mahagoni* L. (Jacq)	(16)
5	Guava	*Psidium guajava* L.	(17)
6	Cashew	*Anacardium occidentale* L.	(18)
7	Avocado	*Persea amaericana* Mill	(18)
8	Apple	*Malus domestica* Borkh.	(19)
9	Grape vine	*Vitis vinifera* L.	(19)
10	Cotton	*Gossypium* L.	(20)
11	Drumstick	*Moringa olefera* L.	(21)
12	Cocoa tree	*Theobroma cacao* L.	(22)
13	Henna	*Lawsonia alba* Lam.	(23)
14	Mango	*Mangifera indica* L.	(24)
15	Black pepper	*Piper Nigrum* L.	(24)
16	Rose apple	*Syzygium jambos* L. (Alston)	(24)
17	Tree of heaven	*Ailanthus excels* Roxb.	(25)
18	Portia tree	*Thespesia populnea* L.	(12)
19	Amla	*Emblica officinalis* L.	(3)
20	Cotton	*Gossypium barbadense* L.	(3)
21	Cotton	*Gossypium hirsutum* L.	(3)
22	Lettuce	*Lactuca runicata DC*	(3)
23	Cow pea	*Vigna ungigulata* L. (Walp)	(3)
24	Indian jujube	*Zizyphus mauritiana* Lam	(3)
25	Neem	*Azadirachta indica* A.Juss.	(26)
26	Calabur tree	*Muntingia calabura* L.	(27)
27	Custard Apple	*Annona* spp.	(28)
28	Bandicoot Berry	*Leea* sp.	(29)
29	Flowering Murdah	*Terminalia paniculata* Roth	(29)
30	Indian almond	*Terminalia catappa* L.	(30)
		B. *Helopeltis theivora*	
31	Tea	*Camellia sinensis* L. (Kuntze)	(31)
32	Red cinchona	*Cinchona pubescens* Vahl	(32)
33	Dhobi tree	*Mussaenda frondosa* L.	(32)
34	Bamboo	*Ochlandra travancorica* Benth	(32)
35	Guava	*Psidium guajava* L.	(32)
36	Indian acalypha	*Acalypha indica* L.	(33)
37	Cashew	*Anacardium occidentale* L.	(34)
38	Jack fruit	*Artocarpus heterophyllus* Lam	(34)
39	Black-jack	*Bidens pilosa* L.	(34)
40	Camphor tree	*Cinnamomum camphora L.*	(34)
41	Coffee	*Coffea arabica* L.	(34)
42	Coral tree	*Erythrina sp.*	(34)
43	Mango	*Mangifera indica* L.	(34)
44	Chinaberry	*Melia azadirachta* L.	(34)
45	Passion flower	*Passiflora* sp.	(34)
46	Coomon tephrosia	*Tephrosis* sp.	(34)
47	Cocoa	*Theobroma cacao* L.	(34)
48	Edible Leaf Eurya	*Eurya acuminate* DC	(35)
49	Jasmine	*Jasminum scandens* Vahl	(35)
50	East-Asian Wild Berry	*Maesa ramentacea* Roxburgh.	(35)
51	Malabar Melastom	*Melastoma malabathricum* L.	(35)
52	Red Nongmangkha	Phlogacanthus *thrysiflora* Nees	(36)
53	Greenbriers	*Similax sp.*	(36)
54	Neem	*Azadirachta indica* A.Juss.	(26)
55	Cape jasmine	*Gardenia jasminoides* Ellis	(37)
56	Indian hemp	*Cannabis sativa* L.	(38)
57	Indian Cherry	*Cordia dichtoma* G. Forst.	(38)
58	Hibiscus	*Hibiscus* sp.	(38)
59	Mulberry	*Morus* sp.	(38)
60	burflower-tree	*Neolamarckia cadamba* Roxb.	(38)
61	Wood sorrel	*Oxalis acetosella* L.	(38)
62	Som	*Persea bombycina (*King ex. Hook. F)	(38)
63	Pepper	*Piper* sp.	(38)
64	Flannel weed	*Sida cordifolia* L.	(38)
65	Java Plum	*Syzygium cumini* L.	(38)

66	Weeping fig	*Ficus benjamina* L.	(39)
67	Jungle geranium	*Ixora coccinea*	(39)
68	Bitter vine	*Mikania micrantha*	(40)
69	Siam Weed	*Chromolaena odorata* L.	(41)
70	Ukshi	*Getonia floribunda* Roxb. (Lamk.)	(29)
71	Lantana	*Lantana camera* L.	(29)
72	Indian Lotus Croton	*Macaranga peltata* (Roxb.) Mueller	(29)
73	Grape-leaf Wood Rose	*Merremia vitifolia* (Burm. F.) Haillier F.	(29)
74	Strychnine tree	*Strychnos nux-vomica* L.	(29)
75	Copperleaf	*Acalypha wilkesiana* J.W. Moore	(42)
76	Custard apple	*Annona squamosa* L.	(42)
77	Soapbush	*Clidemia hirta* (L.) D. Don	(42)
78	Paatha	*Cyclea peltate* (Lam.) Hook. F. and Thomson	(42)
79	Potato yam	*Dioscorea* sp.	(42)
80	Peruvian primrose-willow	*Ludwigia peruviana* (L.) Hara	(42)
81	Pepper hibiscus	*Malvavicus penduliflorus* DC.	(42)
82	Star Cluster	*Pentas lanceolate* (Forssk.) Delfers	(42)
83	Mexican mint	*Plectranthus amboinicus* (Lour.) Spreng	(42)
84	Turkey berry	*Solanum torvum* sw.	(42)
85	Creeping skin flower	*Duranta repens* L.	(42)
86	Spiny amaranth	*Amaranthus* sp. L.	(43)
87	Brinjal	*Solanum melongena* L.	(43)
		C.*Helopeltis bradyi*	
88	Tea	*Camellia sinensis* (L.) Kuntze	(44)
89		*Cephaelis angustifolia* Ridl.	(44)
90	Red cinchona	*Cinchona pubescens* Vahl	(44)
91	Potato yam	*Dioscorea* sp.	(44)
92		*Oxalis* sp.	(44)
93	Chilli	*Capsicum* sp.	(13)
94	Citrus	*Citrus* sp.	(13)
95	Sydney Blue Gum	*Eucalyptus saligna* Sm.	(13)
96	Gutta-percha tree	*Palaquium gutta* Hook.	(13)
97	Cocoa	*Theobroma cacao* L.	(1)
98	Wood sorre	*Acacia mangium* Willd.	(45)
99	Coffee	*Coffea arabica* L.	(45)
100	Cashew	*Anacardium occidentale* L.	(29)
101	Siam Weed	*Chromolaena odorata* L.	(29)

Table 2. Morphological differences among *Helopeltis* species.

Name of the species	Description details
H. antonii	Adults measure approximately 6.0-8.0 mm and are reddish-brown with a black head, red thorax and a black-and-white abdomen. The nymphs are also reddish-brown and elongated. Males live for 9-10 days, while females have a lifespan of 7-8 days, with females being larger than males.
H. bradyi	Females are larger than males, ranging from 6.0-8.8 mm. This species has coloration similar to *H. antonii*, but the hind legs feature a distinct white band at the base.
H. theivora	Adults range from 5.5-8.0 mm in length and have a brownish-yellow pronotum and green abdomen. They possess a slender and elongated body with a yellowish-brown or olive green head, dark red thorax and a yellow-and-greenish-black abdomen.
Pachypeltis maesarum	This species does not have a pin-like knobbed process, features a white scutellum and has short antennae (14).

Biology of Tea Mosquito bug

TMB is a paurametabolic insect, has three stages (Fig. 2) in its life cycle the egg stage, five nymphal instars and the adult stage (Table 3). Mating usually takes place during the night, with occasional occurrences in the morning and evening. Copulation generally begins two days after the adults emerge, starting when the male approaches the female. The male mounts the female and once copulation begins, they assume a tail-to-tail position. The copulation process lasts for about 1-2 hours (46). The fecundity of *H. antonii* on cashew ranges from 10 to 41 eggs (47) and 28 to 35 eggs (48). For *H. antonii*, fecundity on cashew and guava ranges from 10 to 220 and 48 to 185 eggs, respectively. In contrast, *H. theivora* deposits 172 eggs on tea and 63 eggs on cocoa, while *H. bradyi* has a fecundity of 235 eggs per female (49). *H. antonii* lays white, oval-elongated eggs that display lateral compression and are marginally narrower at the apex. On the upper half of fertilized eggs, an orange band appears two to three days after oviposition. The distal area turns dark orange when the eggs get closer to hatching. The nymphs pierce the chorion during the hatching process and come out headfirst. Unfertilized eggs, on the other hand, gradually dry out and shrivel up while staying white and uncolored (50). When eggs are embedded within plant tissues, only the two extra-chorionic processes can be seen, with the egg's exit side exposed on the plant surface (51). The first instar nymph is orange yellow, with red eyes and maroon antennae. The head, legs and abdomen are a dull light orange. This instar lacks a scutellar horn and wing pads and the appendages are fringed with hair. The second instar nymph is uniformly deep orange, including the head, antennae, legs, thorax and abdomen (Table 4). Unlike the previous instar, the body is relatively smooth with no prominent fringe of hairs. The third

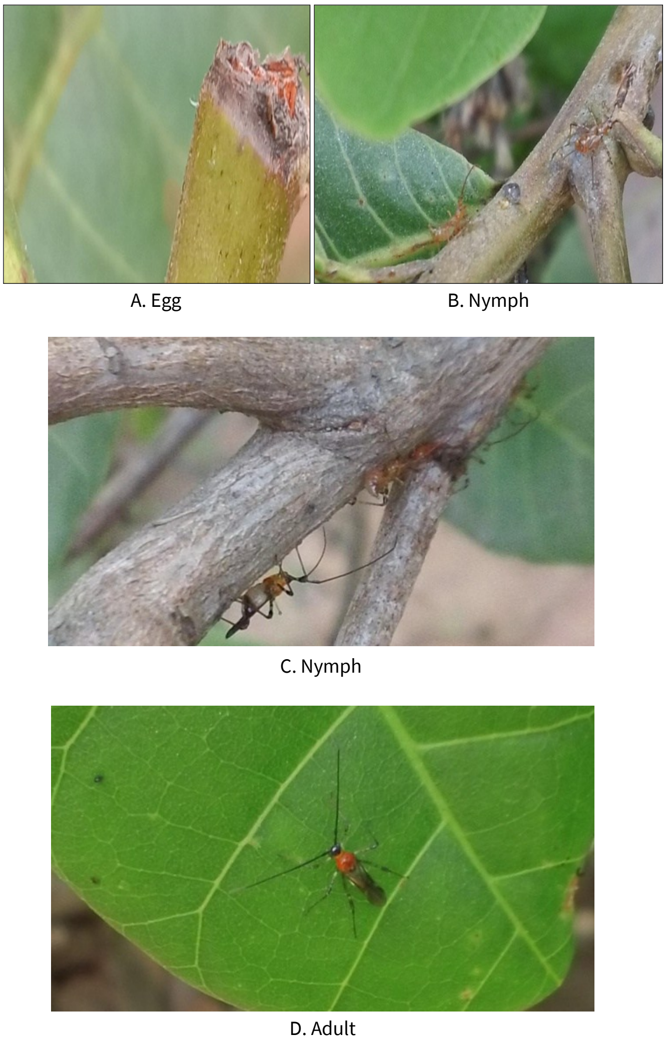

Fig. 2. Biology of Tea mosquito bug.

Image Source: Dr. S. Jaya Prabhavathi, TCRS (TNAU), Yethapur, Salem District, Tamil Nadu, INDIA

Table 3. Biology of tea mosquito bug on different crops

Life stages		Moringa Duration (Days)	Cashew Duration (Days)	Neem Duration (Days)
Egg period		5.55 ± 1.17	8.92 ±1.15	7.45 ± 1.19
Nymphal period	I instar	3.29 ± 0.41	2.48 ± 0.51	3.45 ± 0.51
	II instar	3.53 ± 0.87	2.48 ± 0.51	2.8 ± 0.62
	III instar	3.14 ± 0.36	2.44 ± 0.51	2.45 ± 0.51
	IV instar	3.49 ± 0.23	2.64 ± 0.49	2.65 ± 0.49
	V instar	3.49 ± 0.23	3.16 ± 0.75	4.65 ± 0.67
	Total	16.75 ± 1.13	13.20 ± 1.04	16.05 ± 1.28
Adult longevity	Male	5.16 ± 0.74	9.20 ± 1.66	17.85 ± 1.63
	Female	6.65 ± 0.68	12.08 ± 1.71	19.2 ± 1.88
Total life cycle		27.45 ± 2.09	30.43 ± 1.72	41.9 ± 2.99

instar nymph is light brownish and can be distinguished by the presence of a club-shaped scutellar horn and more prominent, rudimentary wing pads. In the fourth instar, the nymph is deep brown, with more prominent wing pads that do not overlap and well-developed scutellar horns. The fifth instar nymph is deep brownish with a reddish-purple thorax. The antennae and appendages are more intensely colored than the abdomen, with wing pads overlapping the scutellar horn and well-developed, two-segmented tarsi (50). The rate of nymphal development is affected by climatic factors and/or rearing

Table 4. Morphometrics of TMB eggs, nymphs and adults

Stage	Length (mm)	Range (mm)	Breadth (mm)	Range (mm)
Egg	1.15 ± 0.05	1.08-1.25	0.36 ± 0.02	0.33-0.40
1st instar	1.42 ± 0.09	1.30-1.58	0.30 ± 0.03	0.25-0.35
2nd instar	2.33 ± 0.10	2.15-2.48	0.37 ± 0.04	0.32-0.42
3rd instar	2.67 ± 0.03	2.60-2.73	0.48 ± 0.04	0.43-0.55
4th instar	4.34 ± 0.20	3.88-4.60	0.88 ± 0.06	0.80-1.00
5th instar	5.16 ± 0.14	4.85-5.38	1.48 ± 0.09	1.31-1.65
Adult female	8.05 ± 0.08	7.92-8.22	1.85 ± 0.07	1.70-1.96
Adult male	7.01± 0.06	6.90-7.10	1.50 ± 0.06	1.40-1.60

conditions, such as temperature and relative humidity (52). The *Helopeltis* species are mostly found to occur in the continuous cycle of generations throughout the year. The build-up of populations of *H. antonii* on cashew in October- November is synchronized with the emergence of new foliage following the cessation of the monsoon rains. Peak abundance is reached in January-February when cashew trees are in full bloom, the insects remain active on the plants until the onset of the monsoon rains in June. *Helopeltis* populations fluctuate in response to more localized and less regular climatic events, tending not to do well under conditions of heavy rain, high winds or low relative humidity. Whereas *H. theivora* revealed that the pest incidence is most severe from May to September in India and was active in early morning and late afternoon, in shaded area, in cloudy and in dull day. During daytime having sunshine, they usually would hide in the tea bushes or among the weeds present in tea fields. The longevity of female and male *H. theivora* on cashew was 36.8 and 33.6 days (Table 3), respectively (53). In contrast, the longevity of *H. antonii* ranges from 7 to 46 days (49).

Symptoms of damage caused by Tea mosquito bug

The TMB feeds by removing the contents of individual plant cells without rupturing the cell walls. Both nymphs and adults of TMB first tap the plant surface with the tip of their labium, then quickly insert the stylet to a minimum depth of 0.3 mm. Water-soaked lesions appear within a minute of stylet insertion, indicating rapid diffusion of salivary secretions. This is followed by melanization and necrosis of the feeding lesions (3). In cashew, TMB causes necrosis of tissues around the stylet entry point. This leads to black scab formation due to phytotoxins present in its saliva during feeding on tender shoots or inflorescences. These lesions turn pinkish brown within 24 hours and blacken in 2-3 days. Feeding on young leaves results in crinkling, while affected shoots develop elongated black lesions, potentially causing die-back in severe cases. Infested inflorescences typically blacken and die, with immature nuts often dropping. Severe infestations result in a scorched appearance, with the death of shoots and growing tips (54). On guava fruits, TMB infestation results in scab-like lesions (55), while in neem trees, it causes the leaves to turn brown, making the entire tree appear scorched and lifeless (7). TMB activity is most intense during the flowering and fruiting stages of guava (56). Key symptoms of TMB damage in guava include necrotic spots on leaves and scab formation on fruits (57). Also *H. antonii* as an emerging and severe pest of guava, leading to substantial yield losses (58). In moringa, TMB primarily attacks young twigs, flowers and occasionally pods. This feeding causes the twigs and flowers to dry out, giving the tree a wilted appearance, often accompanied by the secretion of honey-like resin (56). *H. clavifer* salivary glands contain pectinase, as previously reported (59). Additionally, the salivary glands of *H. antonii* contain free amino acids, oxido-reductase enzymes and hydrolytic enzymes. These salivary enzymes are involved in detoxifying defense compounds, particularly in neem and in causing phytotoxemia on various host plants (26). The adults prefer to feed on tender leaves, causing damage to the plant foliage and resulting in inflorescence drying and corky outgrowths on the fruits. Additionally, the feeding punctures caused by *H. antonii* result in the exudation of a resinous gummy substance, which is a visible symptom of the infestation (60). In advanced stages of the attack, leaves can suffer complete damage and withering (Fig. 3), which may result in crop losses of up to 50 % (43). TMB can cause complete destruction of cashew (Fig. 4) crops (42).

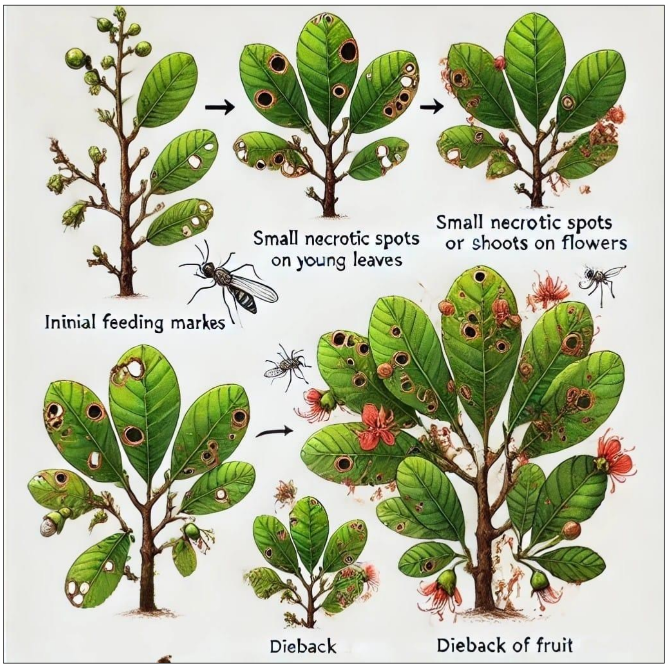

Fig. 3. Symptom development process of TMB on cashew.

(Both nymphs and adults feed by sucking the plant parts, injecting polyphenol oxidase - salivary enzymes).

Integrated pest management of Helopeltis Species

Integrated Pest Management (IPM) is an eco-friendly and sustainable approach to pest control that aims to manage pest populations while minimizing risks to human health, beneficial organisms and the environment. It combines multiple strategies and practices, including biological, cultural, mechanical and chemical methods, to create a comprehensive pest management plan.

Cultural methods

Managing TMB infestations requires a combination of Indigenous Technical Knowledge (ITK) and cultural practices. Farmers in various regions have developed innovative methods to control TMB populations using locally available resources. Alongside ITK, cultural practices like pruning, nutrient management and canopy regulation have proven effective in reducing pest damage and improving crop health. In Assam, India, small tea growers have developed ITK for managing pests, particularly the TMB (*H. theivora*), using locally available plant or animal ingredients (61). Similarly, in China, farmers observed that sunflower seed oil mixed with soapberry solution could suppress oviposition by TMB, leading to the development of an ITK-based approach (62). High soil potash levels have a major impact on the population of TMBs, according to a study looking at the interaction between TMBs and different types of soil. The study also discovered that TMB attacks were more common in fields with low available potash to available phosphorus ratios (63). Furthermore, the verification of the 'Push and Pull' method has surfaced as a fresh and encouraging technique for TMB management (42). To get rid of inserted eggs and early instar nymphs of the TMB species, a frequent plucking is necessary. At common infestation sites, this technique is quite successful in lowering the populations of early nymphal instars and the egg load. Techniques like black plucking, hard plucking and level-off skiff operations have been shown to be effective in cases of severe infestation because they cut off the bug's food sources (63), which reduces the infestation levels for the following generation (64). Pruning is another effective method for managing TMB, as it helps lower the population, prevents further buildup and reduces spread. Additionally, pruning has the added benefit of opening the tree canopy, allowing better air circulation and light penetration, which creates unfavorable conditions for pest population growth. In the TMB infested sections of tea plantations, pruning and skiffing should be conducted from the periphery towards the center and a few bushes should be untouched for a day or two in the center to serve as a trap for adults. These bushes should be pruned or skiffed after spraying with suitable insecticides. This technique helps to provide efficient control of the TMB. The TMB prefers moist conditions and mild temperatures. For that reason, this pest is often observed in large numbers on tea plants under heavy shade. However, an unshaded condition receiving full sunshine is equally detrimental because this enhances attacks of other pests such as leafhoppers, thrips and red spider mites. Research has shown that tea plantations with 60 % shade experienced the lowest pest infestation and improved crop yield (63). The integration of ITK and cultural practices like pruning, soil nutrient management and regular plucking offers sustainable and effective solutions for controlling TMB populations. These methods, when tailored to local conditions, not only reduce pest damage but also enhance crop productivity and resilience.

Biological methods

Biological control plays a crucial role in sustainable pest management, utilizing natural enemies to regulate pest populations. Various predators, parasitoids and pathogens have shown significant potential in controlling *Helopeltis* species, in different plantation ecosystems. Numerous studies have explored the efficacy of these biological agents, demonstrating their effectiveness in reducing pest populations. Egg parasitoid, *Telenomus* species are often highly specific to their host, making them effective in targeting *Helopeltis* eggs and thereby reducing the pest

A. Adult TMB sucking juice

B. As a result tip drying of leaves

C. Dried plant twigs and flowers

D. Dried plant twigs and flowers

E. Dried plant twig tip

F. Feeding punctures of TMB

G. Damage in the developing nut and apple

H. Damage in the developing nut and apple

I. Damage in the young nuts

J. Female TMB laying egg

K. Heavily infested tree- scorched appearance

L. Heavily infested tree- scorched appearance

Fig. 4. Symptoms of TMB on cashew tree.

Image Source: Dr. S. Jaya Prabhavathi, TCRS (TNAU), Yethapur, Salem District, Tamil Nadu, INDIA population. Their success is influenced by factors such as the timing of their release and environmental conditions like temperature and humidity. Four species of egg parasitoids attacking *Helopeltis* spp. have been reported: *Telenomus* sp., *Ufens* sp., *Chaetostricha* sp. (Trichogrammatidae), *Erythmelus helopeltidis* Gahan and *Gonatocerus* sp. (65). The occurrence of a *Leiophron,* nymphal-adult parasitoid attacking *H. antonii*. This observation highlights another potential biological control agent for *H. antonii* (27). The diversity of spiders in the cashew ecosystem was explored, revealing the presence of 117 species of spiders across 18 families. Among these, *Telamonia dimidiata* and *Oxyopes shweta* were identified as significant predators of *Helopeltis* species. This finding underscores the role of these spider species in the natural biological control of *Helopeltis*, which are major pests in cashew plantations (66). The study highlights the importance of conserving spider diversity to enhance pest management in agricultural ecosystems. The presence of three ant genera, *Tetraponera*, *Crematogaster* and *Oecophylla* as predators of *Helopeltis* species. These ants play a crucial role in the natural control of *Helopeltis*, a major pest in various crops. Further supporting the importance of ants in pest management, a field experiment was conducted showing that the population of Tea Mosquito Bug (TMB) was significantly lower in plants colonized by red ants, highlighting the potential of these ants as effective biological control agents in agricultural ecosystems (67). *Chrysoperla carnea* Stephens acts as a predator of *H. theivora* (68). Praying mantids have also been documented feeding on *H. theivora* (69). *Aspergillus flavus* Johann and *A. tamarii* have been known to infect *H. antonii* (70). An entomopathogen, *Beauveria bassiana* Bals., was isolated from *H. antonii* infesting guava (71). *Beauveria bassiana* has shown great potential as a biological control agent against *H. antonii*, causing 100 % mortality in bioassay studies (72). It is also effective against the tea mosquito bug, *H. theivora*, in Assam (73). The combination 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 (74). Kernel extracts from *Pongamia*, *Calophyllum* extracts resulted in higher mortality of *H. antonii* compared to other plant extracts (70). Additionally, the aqueous extract of *Clerodendrum viscosum* L. significantly reduced both the mite population and *H. theivora* infestation in tea by 68 to 95 % and 73 to 86 %, respectively, demonstrating bioefficacy comparable to synthetic and neem pesticides (75). The findings showed that *Pseudomonas fluorescens* MP-13 chitinase achieved 100 % mortality, whereas *Bacillus cereus* C-13 chitinase resulted in 78 % mortality of TMB (76). The integration of biological control agents, including parasitoids, predators, pathogens and plant -based solutions, offers a sustainable approach to managing *Helopeltis* species in agricultural ecosystems. Conservation of natural enemies like spiders and ants, along with the use of entomopathogens and plant extracts, can significantly reduce pest populations and minimize the reliance on chemical pesticides, promoting healthier and more resilient crop systems.

Physical methods

Effective management of the TMB requires the integration of physical, biological and pheromonal control techniques. Several approaches, including manual collection, ultrasound technology and pheromone-based trapping, have shown promise in controlling TMB populations, offering eco-friendly alternatives to chemical pesticides. Hand collection of the adults and nymphs is best carried out during the early morning, late afternoon and night when the insects are most active on the top branches of tea bushes (77). Ultrasound is a physical technique that causes a great deal of stress in TMB, resulting in hyper feeding at first, then decreased feeding, oviposition and lifespan. When subjected to ultrasound at a frequency of 20 kHz for 15, 30 and 45 min per day, early death of TMB larval instars was noted (78). Against this insect, programs utilizing IPM may find it useful to employ ultrasound-based management. Furthermore, pheromonal research has advanced significantly, especially regarding the application of pheromone baits in TMB control. Mass trapping successfully decreased the number of insects and the extent of infection, as these sex pheromone traps of TMB using virgin females to attract the males, have been successfully demonstrated in many estates in the Anamallais. The advantage of this trap is that it is species specific. One newly hatched virgin female was placed in the central cage of the pheromone trap. Females were changed twice a week and fed on tender tea shoots. On an average, a single trap attracted 100 to 500 males per day (79). This method of trapping adult male TMBs is very effective, economical and safe for the environment. The combination of manual collection, ultrasound technology and pheromone-based traps offers a comprehensive and sustainable approach to TMB management.

Chemical methods

Effective management of the TMB is essential for maintaining crop health, particularly in neem and other susceptible plants. Recent studies have highlighted various insecticides and their effectiveness against *H. antonii*, underscoring the importance of selecting appropriate chemical controls in pest management strategies. Among tested insecticides, Lambda-cyhalothrin 25 EC and thiamethoxam 25 WG showed the highest efficacy against *H. antonii* on neem (46). Clothianidin 50 % WDG and thiamethoxam 12.60 % + Lambda-cyhalothrin 9.5 % ZC have been reported to achieve the highest mortality rates in controlling *H. antonii* (80). Generally, Lambda-cyhalothrin has been suggested as an effective alternative insecticide for controlling *H. antonii* (81). The Central Insecticides Board and Registration Committee (CIB&RC) has recently approved several chemicals for managing TMB populations, including bifenthrin 8.0% SC at 40 a.i. ha^{-1}, clothianidin 50 % WDG at 60 a.i. ha^{-1}, thiacloprid 21.70 % SC at 90 a.i. ha^{-1}, thiamethoxam 25 % WG at 25 a.i. ha^{-1} and a combination of thiamethoxam 12.6 % + lambda-cyhalothrin 9.5 % ZC at 33 a.i. ha^{-1}. If TMB infestation exceeds 10 % on the terminal shoot, applying thiacloprid 240 SC at 1.5 mL L^{-1} or profenophos 50 EC at 2 mL L^{-1} can effectively control the pest, especially on *Ailanthus excelsa* (82). Study on the TMB and sex-based variation in pesticide sensitivity and tolerance, females are more likely to survive when exposed to the recommended pesticide dose, which results in a population with higher insecticide tolerance (83). Furthermore, based on comparisons between the recommended dosages of widely used insecticides and the LC50 values of effective field dosages, the study found a 1.5 to 82.9-fold reduction in susceptibility in the TMB test population (84). The integration of effective insecticides, such as lambda-cyhalothrin and thiamethoxam, along with an understanding of population dynamics and pesticide tolerance, is crucial for managing TMB populations effectively. Continued research and monitoring are necessary to adapt pest management strategies that address resistance and ensure sustainable control methods in agricultural practices.

Resistance of H. theivora to pesticides

A significant challenge in controlling *H. theivora* is its ability to quickly develop resistance to frequently used insecticides (85). This is exacerbated by their high reproductive potential and multiple annual generations, along with the continuous and repeated use of various insecticidal active substances on tea cultivations over many years at a rate of 7.5 L/ha. This persistent use has not only limited the effectiveness of natural enemies in controlling *H. theivora* populations but also led to resurgences and the development of resistance, ultimately resulting in control failures (75). Such failures have already been observed with organophosphorus, organochlorine and synthetic pyrethroid insecticides and more recently with neonicotinoids (86). Protection of plantations from *Helopeltis* requires a comprehensive understanding of the pests' intricate biology and feeding behaviors (87).

Conclusion

Helopeltis species are notorious for inflicting substantial damage on economically important crops such as tea, coffee and cashew, leading to significant economic losses for farmers and the agricultural sector. This pest not only damage the foliage but can also affect the overall vitality of the plants, leading to reduced yields and compromised quality. Effective management of *Helopeltis* infestations is achieved through a multifaceted approach that combines cultural practices, biological control and the judicious use of chemical interventions. Cultural practices, such as proper pruning, timely harvesting and maintaining healthy plant conditions, can help create an environment less conducive to pest outbreaks. Biological control, involving natural enemies like predators and parasitoids, provides a sustainable alternative to chemical pesticides, helping to regulate pest populations naturally. Integrated Pest Management (IPM) remains a cornerstone of effective control, balancing these diverse approaches to minimize pest impact while maintaining environmental sustainability. Emphasizing education and outreach will further empower farmers with the knowledge and tools necessary to implement effective pest management strategies, ensuring the vitality of plantations for generations to come.

Acknowledgements

Nil

Authors' contributions

Each author has made an active contribution. SJP, SK and RG carried out in writing original draft and summarizing. AK, BN helped in writing review and summarizing and SKN reviewed the manuscript, helped in editing and summarizing. SE contributed by developing the ideas of manuscript and coordination. SRV helped in summarizing and revising 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 interests to declare.

Ethical issues: None

Did you use generative AI to write this manuscript? Yes

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the author(s) used AI ChatGPT to improve language and readability. After using this tool, the authors reviewed and edited the content as needed and took full responsibility for the content of the publication.

References

1. De Silva MD. A new species of *Helopeltis* (Hemiptera: Heteroptera, Miridae) found in Ceylon. Bull Entomol Res. 1957; 48:459–61. https://doi.org/10.56093/ijas.v86i2.55868
2. Stonedahl GM. The Oriental species of *Helopeltis* (Heteroptera: Miridae): a review of economic literature and guide to identification. Bull Entomol Res. 1991;81:465–90. https://doi.org/10.1017/s0007485300032041
3. Sundararaju D. Studies on Helopeltis spp. with special reference to *H. antonii* Sign. in Tamil Nadu. PhD Thesis, Tamil Nadu Agricultural University, Coimbatore, India; 1996. p. 210. https://doi.org/10.5513/JCEA01/18.1.1875
4. Mandal RC. Cashew Production and Processing Technology. Agrobios India; 2000. p. 195.
5. Srikumar KK, Bhat PS. Field survey and comparative biology of tea mosquito bug (*Helopeltis* spp.) on cashew (*Anacardium occidentale* Linn.). J Cell Anim Biol. 2012;6(14):200–06. https://doi.org/10.5897/JCAB11.094
6. Varma RV, Balasundaran M. Tea mosquito (*Helopeltis antonii*) feeding as a predisposing factor for entry of wound pathogens in cashew. Entomon.1990;15(3-4):249–51. https://www.cabidigitallibrary.org/doi/full/10.5555/19921175255
7. Handa AK, Sirohi C, Arunachalam A, Ramanan SS, Rajarajan K, Krishna A, Kolse RH. Surge in neem tea mosquito bug incidence in India. Curr Sci. 2022;122(6):651.
8. Anonymous. Indian society for plantation crops, central plantation crops research institute, Kasargod, India, Report; 1984: 111-115. https://cpcri.icar.gov.in.
9. Anandkumar V, Hugar PS, Hiremath SM. Seasonal incidence of tea mosquito bug, *Helopeltis* spp. in guava, cv. L-49 at MARS, Dharwad, Karnataka. BFAIJ. 1984;14(1):1262–68. https://doi.org/10.9734/jabb/2024/v27i111734
10. Sundararaju D. Seasonal abundance and extent of damage of tea mosquito bug on cashew. JPC. 1984;33(1):53–8. https://doi.org/10.22271/j.ento.2020.v8.i6aa.8118

11. Sundararaju D, John NJ. Susceptibility of cashew accessions to *Helopeltis antonii* (Heteroptera: Miridae), in the preflowering phase. JPC. 1993;21:50–3.

12. Sundararaju D, Bakthavatsalam N. Pests of cashew. (In) Advances in Horticulture, Chadha K L and Rethinam P (Eds). Malhotra Publishing House, New Delhi; 1994. p. 759–85. https://doi.org/10.1007/s12595-013-0091-2

13. Lever RJAW. The tea mosquito bugs (*Helopeltis* spp.) in the Cameron Highlands. Malay Agric J. 1949; 32:91–108. https://doi.org/10.5897/JCAB11.094

14. Vanitha K, Raviprasad TN. Tea mosquito bug and its management in cashew. The director ICAR – DCR, puttur; 2020. http://krishi.icar.gov.in/jspui/handle/123456789/43497

15. Firake DM, Sankarganesh E, Yeshwanth HM, Behere GT. Mirid bug, *Helopeltis cinchonae* Mann: a new pest of economically important horticultural crops in Northeast India. Phytoparasitica. 2020; 49:317-26. http://doi.org/10.1007/s12600-020-00855-y

16. Fletcher TB. Some South Indian Insects. Government Press, Madras, India; 1914. p. 488-489. https://doi.org/10.5962/bhl.title.44262

17. Ayyar TVR. Hand Book of Economic Entomology for South India. Government Press, Madras, Tamil Nadu, India; 1940. p. 518. https://doi.org/10.1038/149009d0

18. Puttarudriah M. Blister disease "Kajji" of guava fruits (*Psidium guava*). Mysore Agric J. 1952 28:8-13. https://doi.org/10.5897/AJAR2012.2157

19. Puttarudriah M, Appanna M. Two new hosts of *Helopeltis antonii* in Mysore. Indian J Entomol. 1955; 17:91-392. https://www.cabidigitallibrary.org/doi/full/10.5555/19570500656

20. Puttarudriah M. A dangerous pest of cotton. Indian Cotton Growing Review. 1958;12:406-07. https://doi.org/10.55446/IJE.2022.167

21. Pillai GB, Singh V, Dubey OP, Abraham VA. Seasonal abundance of tea mosquito *Helopeltis antonii* on cashew tree in relation. to meteorological factors. In: Proceeding of the International Cashew Symposium, Cochin; 1979. p. 103-110 https://doi.org/10.17660/ActaHortic.1985.1081.19

22. Abraham CC, Remamony KS. Pests that damage cocoa plants in Kerala. Indian Arecanut, Spices & Cocoa Journal. 1979;2(3):77-81. http://hdl.handle.net/123456789/8359

23. Sundararaj D. Cashew pests and their natural enemies in Goa. JPC. 1984; 12: 38-46.

24. Devasahayam S, Nair CPR. The tea mosquito bug *Helopeltis antonii* Signoret on cashew in India. JPC. 1986;14:1-10. https://doi.org/10.56093/ijas.v86i2.55868

25. Satapathy CR. Bioecology of major insect pests of cashew (*Anacardium occidentale* Linn.) and evaluation of certain pest management practices. PhD Thesis, University of Agricultural Sciences, Bangalore, India; 1993.p. 224. https://doi.org/10.1007/s42690-021-00527-2

26. Sundararaju D, Sundarababu PC. *Helopeltis* spp. (Heteroptera: Miridae) and their management in plantation and horticultural crops of India. JPC. 1999;27:155–74. http://doi.org/10.1017/S0007485300032041

27. Sundararaju D. Description of endoparasitism in nymph and adults of *Helopeltis* spp. infesting cashew. JPC. 2002;30: 66–8.

28. Rami RPV. Record of tea mosquito bug, *Helopeltis antonii* (Homoptera: Miridae) on the fruits of *Annona* spp. PMHE. 2002; 15 (1):74-76.

29. Vanitha K, Srikumar KK, Bhat PS. Record of weed flora of cashew plantations as hosts of tea mosquito bug. The Ecoscan. 2014; 8 (3&4): 221-24.

30. Rakhesh S, Udikeri SS, Hanchinal SG, Mahantesh ST, Naik CB, Prabhulinga T, et al. A survey on *Helopeltis antonii* signoret infesting Indian almond, *Terminalia catappa* L. Int J Econ Plants. 2024;11(2):131-6. https://doi.org/10.23910/2/2024.5269a

31. Mann HH. Notes on a disputed point in the life history of *Helopeltis theivora*. J Asiat Soc Bengal. 1902;71:133-34. https://biostor.org/reference/279937

32. Anstead RD, Ballard E. Mosquito blight of tea. Planters Chronicle. 1922; 17:443-447. https://www.cabidigitallibrary.org/doi/full/10.5555/19220501467

33. Das GM. Pest of tea in North-East India and their control (Memorandum No. 27). Jorhat Tocklai Experimental Station, Tea Research Association; 1965. p. 169-173. https://www.cabidigitallibrary.org/doi/full/10.5555/19660305768

34. Rao GN. *Helopeltis*: A breakthrough in its control. UPASI Tea Science Department Bulletin. 1970; 28:21-24. https://doi.org/10.54083/PHA/1.2.2023/18-28

35. Das SC. Resurgence of tea mosquito bug, *Helopeltis theivora* Waterhouse, a serious pest of tea. Two and a Bud. 1984; 31 (2): 36-39. https://www.cabidigitallibrary.org/doi/full/10.5555/19860533308

36. Somchoudhury AK, Samanta A, Dhar P. Tea science and human health. In: Proceedings of Tea Research Association of India; 1993. p. 330-338.

37. Kalita H, Deka MK, Singh K. Diet breadth of tea mosquito bug, *Helopeltis theivora* Waterhouse (Hemiptera: Miridae). Crop Res. 2000; 19(1):122-24. https://www.cabidigitallibrary.org/doi/full/10.5555/20001108808

38. Tocklai TRA. Special bulletin on Tea mosquito bug, *Helopeltis theivora* Waterhouse. Tocklai Experimental station, TRA, Assam, India; 2010. p. 10.

39. Gogoi B, Choudhury K, Sharma M, Rahman A, Borthakur M. Studies on the host range of *Helopeltis theivora*. Two and a Bud. 2012; 59:31-34.

40. Saha D, Mukhopadhyay A, Bahadur M. Effect of host plants on fitness traits and detoxifying enzymes activity of *Helopeltis theivora*, a major sucking insect pest of tea. Phytoparasitica. 2012; 40(5): 433-44. https://doi.org/10.1007/s12600-012-0244-2

41. Srikumar KK, Bhat PS. Biology of the tea mosquito bug, *Helopeltis theivora* Waterhouse on *Chromolaena odorata* (L). Chil J Agric Res.2013;73(3):309-14. http://doi.org/10.4067/S0718-58392013000300015

42. Srikumar K, Smitha S, Suresh K, Radhakrishnan B. New host records of tea mosquito bug (*Helopeltis theivora* Waterhouse) in tea plantations of India. J Biol Rec. 2016; 62016: 61-04.

43. Sivakumar T, Yeshwanth HM. New hosts of tea mosquito bug, *Helopeltis theivora* Waterhouse on eggplant (*Solanum melongena* L.) and amaranth (*Amaranthus* sp. L.) from India. Phytoparasitica. 2019;47(4):499-50 http://doi.org/10.1007/s12600-019-00750-1

44. Miller NCE. Insects associated with cocoa (*Theobroma cocoa*) in Malaya. Bull Entomol Res. 1941; 32(1):1-15. https://doi.org/10.1017/S0007485300005186

45. Hamid AA. Insect pests of *Acacia mangium* Willd. In: Sarawak. Research Report FE 1, Sarawak Forest Department; 1987. p. 1-10. https://www.cifor-icraf.org/publications/pdf_files/Insect-pests.pdf

46. Chaitanya B, Bheemanna M, Prabhuraj A, Murthy MS, Harischandra NR, Aswathanarayana DS. Biology and Management of Tea Mosquito Bug, *Helopeltis Antonii* on Neem; 2024. http://doi.org/10.21203/rs.3.rs-4092275/v1

47. Pillai GB, Singh V, Dubey OP, Abraham VA. Seasonal abundance of tea mosquito bug, *Helopeltis antonii* on cashew in relation to meteorological factors. (In) Cashew Research and Development, (Eds): Rao EVVB and Khan HH (Eds). Indian Society for Plantation Crops, CPCRI, Kasaragod; 1984. p. 103–10. https://doi.org/10.22271/j.ento.2020.v8.i6aa.8118

48. Ambika B, Abraham CC. Bio-ecology of *Helopeltis antonii* Sign. (Miridae: Hemiptera) infesting cashew trees. Entomon. 1979; 4:335–42. https://www.cabidigitallibrary.org/doi/full/10.5555/19800578748

49. Srikumar KK, Bhat PS. Comparison of the developmental and survival rates, adult longevity and fecundity of *Helopeltis antonii* Signoret (Hemiptera: Miridae) on different phenological stages of cashew. JPC. 2011;39(3):347–50. https://doi.org/10.5897/JCAB11.094

50. Damasia DM, Patel ZP, Makvana AI. Studies on the biology of tea mosquito bug, *Helopeltis antonii* Signoret (Hemiptera: Miridae) on cashew. Int J Curr Microbiol App Sci. 2020; 11:2381-88.

51. Aravinthraju K, Suresh K, Moorthy AV. Biology of Tea Mosquito Bug, *Helopeltis antonii* Signoret in *Moringa olifera*. Indian J Ecol. 2023; 50(4):1110-12. http://doi.org/10.55362/IJE/2023/4021

52. Sundararaju D, John NJ. Mass rearing technique for *Helopeltis antonii* Sign. (Heteroptera: Miridae) - An Important pest of cashew. JPC. 1992; 20: 46–53.

53. Songyot P, Punpen C. Biology of mosquito bug, *Helopeltis theivora* Waterhouse, an insect pest of cashewnut. Khon Kaen Agr J. 1997; 25(3): 132–38. https://doi.org/10.4067/S0718-58392013000300015

54. Makawana AI, Leua HN, Patel HF, Patel VK, Patel RB, Makati JP. Cashew tea mosquito bug and its management. Rashtriya Krishi. 2017; 2(2):1-3.

55. Patil GR, Naik LK. Studies on the seasonal incidence of tea mosquito bug on guava cultivars. KJAS. 2004; 17(2):339–40.

56. Aravinthraju K, Suresh K, Manisegaran S. Damage and oviposition of tea mosquito bug *Helopeltis antonii* signoret on guava, neem and moringa. Indian J Entomol. 2024:554-56. https://doi.org/10.55446/IJE.2023.816

57. Bose ASC, Rabeena I, Sathyan T. Tea Mosquito Bug (*Helopeltis antonii* Signoret) and its management in Guava. Biotica Res Today. 2020; 2(5 Spl.):333-34.

58. Aravinthraju K, Suresh K, Manisegaran S, Rajamanickam C. Efficacy of certain insecticides Tea Mosquito Bug, *Helopeltis antonii* Signoret in guava. Indian J Entomol. 2020;83(2): 211-12. https://doi.org/10.5958/0974-8172.2021.00071.7

59. Miles PW. Plant-sucking bugs can remove the contents of cells without mechanical damage. Experientia. 1987; 43:937–9. https://doi.org/10.1007/BF01951678

60. Shankara MM, Prabhuraj A Bheemanna M. Occurrence of tea mosquito bug *Helopeltis antonii* Signoret on neem in Northern Karnataka. Indian J Entomol. 2023;85(2):393-95. https://doi.org/10.55446/IJE.2022.537

61. Bhuyan KK, Saikia GK, Dek MK. Validation of ITKs practiced for management of red spider mite infecting tea plantation. J Plant Prot Sci. 2017;25(2):311-14. https://doi.org/10.5958/0974-0163.2017.00016.7

62. Lin ML. Technical development of production and products in organic tea farming. Int J Tea Sci. 2016; 12(01):74-83. https://doi.org/10.20425/ijts.v0iof.9579

63. Roy S, Muraleedharan N, Mukhopadhyay A, Handique G. The tea mosquito bug, *Helopeltis theivora* Waterhouse (Heteroptera: Miridae): Its status, biology, ecology and management in tea plantations. Int J Pest Manag. 2015; 61(3):179-97. https://doi.org/10.1080/09670874.2015.1030002

64. Roy S, Mukhopadhyay A. Insecticide-induced change in egg-laying strategy of *Helopeltis theivora* (Hemiptera: Miridae) on tea shoot *(Camellia sinensis*). Proceedings of the Zoological Society. 2011;64:54-56. http://doi.org/10.1007/s12595-011-0010-3

65. Sundararaju D, Sundarababu PC. Egg parasitoids of neem mosquito bug from cashew. Cashew. 2000; 14(1): 32–4. https://www.cabidigitallibrary.org/doi/full/10.5555/20023023398

66. Bhat PS, Srikumar KK, Raviprasad TN, Vanitha K, Rebijith KB, Asokan R. Biology, behavior, functional response and molecular characterization of *Rihirbus trochantericus* Stal var. luteous (Hemiptera: Reduviidae: Harpactorinae) a potential predator of *Helopeltis* spp. (Hemiptera: Miridae). Entomol News. 2013; 123:264-77. https://doi.org/10.3157/021.123.0409

67. Sreekumar KM, Vasavan N, Madhu S, Sijila J, Sreedharan MP, Sreelekha S. Managing tea mosquito bug in cashew by augmenting red ants. JPC. 2011;39(1):119-22. https://agris.fao.org/search/en/providers/122648/records/647356aa53aa8c8963068555

68. Das S, Roy S, Mukhopadhyay A. Diversity of arthropod natural enemies in the tea plantations of North Bengal with emphasis on their association with tea pests. Curr Sci. 2010; 99(10):1 457–63. https://www.cabidigitallibrary.org/doi/full/10.5555/20103373566

69. Mamun MSA, Ahmed M. Integrated pest management in tea: prospects and future strategies in Bangladesh. J Plant Prot Sci. 2011; 3(2):1–13.

70. Satapathy CR. Bioecology of major insect pests of cashew (*Anacardium occidentale* Linn.) and evaluation of certain pest management practices. PhD Thesis, University of Agricultural Sciences, Bangalore, India; 1993.p. 224. http://krishikosh.egranth.ac.in/handle/1/5810109479

71. Visalakshy PNG, Mani M. Record of *Beauveria Bassiana* on tea mosquito bug, *Helopeltis antonii* Signoret in guava ecosystem. JBC. 2011; 25(2):149–51. https://doi.org/10.18311/jbc/2011/3752

72. Patil GR, Naik LK. Evaluation of mycopathogens against *Helopeltis antonii*. Karnataka Journal of Agricultural Sciences. 2004b; 17:337 -338. https://doi.org/10.5958/2394-4471.2015.00053.2

73. Hazarika L K, Budhinda M B, Hazarika N. Insect pests of tea and their management. Annu Rev Entomol. 2009; 54:267-84. https://doi.org/10.1146/annurev.ento.53.103106.093359

74. Jaya Prabhavathi S, Senthil Kumar M, Rajababu C, Kalpana K, Senthilkumar P, Subrahmaniyan K, et al. Exploration of effect of botanicals on controlling tea mosquito bug, - (*Helopeltis antonii* Signoret) in cashew ecosystem. Plant Sci Today.2025; 12(1):1-12. (Early access). https://doi.org/10.14719/pst.6846

75. Roy S, Gurusubramanian G, Mukhopadhyay A. Variation of resistance to endosulfan in tea mosquito bug, *Helopeltis theivora* Waterhouse (Heteroptera: Miridae) in the tea plantation of the Sub-Himalayan Dooars, northern west Bengal J Entomol Nematol. 2009;1(3):29-35.

76. Suganthi M, Arvinth S, Senthilkumar P. Comparative bioefficacy of *Bacillus* and *Pseudomonas* chitinase against *Helopeltis theivora* in tea (*Camellia sinensis* (L.) O.Kuntze. Physiol Mol Biol Plants. 2020;26(10):2053-60. https://doi.org/10.1007/s12298-020-00875-2

77. Gurusubramanian G, Senthil Kumar N, Tamuli AK, Sarmah M, Rahman A, Bora S, Roy S. Biointensive integrated management of tea pests for sustainable tea production in North East India. In: Manual on tea culture for condensed course (Eds.: A.K. Dutta, N. Ahmed, B. Kotoky and D. Burugohain). Tocklai Experimental Station, TRA, Jorhat Assam Printing Works Private Limited,Jorhat,Assam,India;2005.p.45-59. https://teascience.in/index.php/ijts/article/download/206/144/pdf

78. Borthakur S, Bhuyan M, Bhattacharyya PR, Rao PG. Ultrasound: A potential tool for management of tea mosquito bug, *Helopeltis theivora* Waterhouse (Miridae: Hemiptera). Sci Cult.2011;77(11-12):493-95. https://www.cabidigitallibrary.org/doi/full/10.5555/20123348184

79. Radhakrishnan B, Srikumar KK. Pheromone traps, an efficient tool for the management of tea mosquito bug in tea. Planters Chronicle; (2015).p. 5-10.

80. Elango K, Subramanian J, Marimuthu M, Chinniah M, YS JTE, Subbarayalu M, Iyyamperumal M. In vitro Assessment of Neonicotinoids and Pyrethroids against Tea Mosquito Bug, *Helopeltis antonii* Sign. (Hemiptera: Miridae) on Guava. J Adv Zool.

2023; 44(5):767-71. http://doi.org/10.53555/jaz.v44i5.2901

81. Mahapatro GK. Evaluation of insecticidal sprays for control of Tea Mosquito Bug *Helopeltis antonii* and other insect-pests in cashew. Indian J Entomol. 2008; 70(3):217–22.

82. Manimaran V, Suganthy M, Balasubramanian A, Kumar PP. Management of tea mosquito bug, *Helopeltis antonii* Signoret infesting *Ailanthus excelsa* Roxb. J Entomol Zool Stud. 2019;7 (3):620-23. https://www.entomoljournal.com/archives/2019/vol7issue3/PartK/7-3-22-581.pdf

83. Roy S, Prasad AK. Sex-based variation in insecticide susceptibility and tolerance related biochemical parameters in tea mosquito bug, *Helopeltis theivora*. Phytoparasitica. 2018; 46(3): 405-10. https://doi.org/10.1007/s12600-018-0670-x

84. Roy S, Mukhopadhyay A, Gurusubramanian G. Susceptibility status of *Helopeltis theivora* Waterhouse Srikun (Heteroptera: Miridae) to the commonly applied insecticides in the tea plantation of the Sub-Himalayan Dooars area of North Bengal, India. Resistance Pest Management Newsletter. 2008; 18:10-18.

85. Gurusubramanian G, Bora S. Insecticidal resistance to tea mosquito bug, *Helopeltis theivora* Waterhouse (Miridae: Heteroptera) in North East India. J Environ Res Dev. 2008; 2(4):560-67.

86. Gurusubramanian G, Senthilkumar N, Bora S, Roy S, Mukhopadhyay A. Change in susceptibility in male *Helopeltis theivora* Waterhouse (Jorhat population, Assam India) to different classes of insecticides. Resist. Pest Manage Newsl. 2008; 18(1):36-39. https://www.cabidigitallibrary.org/doi/full/10.5555/20113275935

87. Jaya Prabhavathi, S, M. Senthil Kumar, P. Senthilkumar, K. Subrahmaniyan. editors. Cashew pests and its management. (ISBN: 978-81-977699-8-6), Tapioca and Castor research Station, Tamil Nadu Agricultural University, Coimbatore-3, 2024.