ISSN 0971-6831
Online ISSN 0974-4541

Pest Management in Horticultural Ecosystems

Volume 31 Number 1 July 2025

Association for Advancement of Pest Management in Horticultural Ecosystems (AAPMHE)
ICAR-Indian Institute of Horticultural Research
Hesaraghatta Lake P.O., Bengaluru - 560089, India
(NAAS 2024 Rating : 5.14)
Journal Website : https://pmhe.in

Pest Management in Horticultural Ecosystems

(An international bi-annual scientific journal, published by the Association for Advancement of Pest Management in Horticultural Ecosystems (AAPMHE), Bengaluru, India)

All papers and editorial matters are to be addressed to the Chief Editor, Division of Crop Protection, ICAR - Indian Institute of Horticultural Research, Bengaluru-560 089, India. E-mail: **editorphme@gmail.com**

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***Pest Management in Horticultural Ecosystems* is widely abstracted**

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Acknowledgement: **AAPMHE acknowledges the financial support from the Indian Council of Agricultural Research, New Delhi.**

COVER PHOTOS :

Left: Malabar Parakeet, an emerging pest on small cardamom (**Photo credit:** Dr. M. Nafeesa Cardamom Research Station, KAU, Idukki, Kerala

Right: *Colletotrichum zingiberis* leaf spot on ginger (**Photo Credit:** Dr. Shreeshail Sonyal, KSNUAHS, Shivamogga, Karnataka)

Journal Website :https://pmhe.in

ISSN: 0971-6831
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Editor's Choice

Change of Baton

"Every editor is just a chapter in a larger story. I'm honored to have written mine, and now it's a joy to pass the pen to my successor.. To pass the pen is not to end the story, but to let it be told anew." — Anonymous

My editorial journey with **Pest Management in Horticultural Ecosystems (PMHE)** began in 2008 as an Associate Editor. In 2010 (Volume 16 - 2), I was elevated as the Chief Editor thanks to the confidence and encouragement of Dr. Abraham Verghese, who, after successfully nurturing and popularising the journal for more than 15 years, decided to pass on the baton to the next generation.

Over the years, *PMHE* has witnessed remarkable transformations- the shift to a vibrant, illustrated cover page, an increase in book size, a substantial rise in the number of articles published per volume, complete online processing of manuscripts, and a steady climb in its NAAS rating to 5.14. These milestones reflect the collective efforts of a dedicated editorial team and the ever-growing support of contributors and readers.

I wish to place on record my heartfelt gratitude to all executive council members of AAPMHE, Associate Editors, Editorial Assistants, Reviewers, and Contributors, whose constant support and cooperation made this journey fruitful and cherishable. A very special word of thanks goes to Dr. Abraham Verghese, Former Chief Editor, whose guidance and mentorship helped refine my editorial skills.

As I hand over the mantle to Dr. Prasanna Kumar, the new Chief Editor, I extend my warmest wishes to him and his team. Sincerely hope *PMHE* continues to scale newer heights, inspire scholarship, and strengthen its standing as a journal of excellence.

P. V. RAMI REDDY
Chief Editor

Pest Management in Horticultural Ecosystems
Vol. 31, No.1 pp 1-9 (2025)
DOI Number : 10.5958/0974-4541.2025.00004.7

Diversity and host range of the tribe Saissetiini (Hemiptera: Coccomorpha: Coccidae) in Kerala, India

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ABSTRACT: Purposive field surveys were conducted during 2021-2025 across different districts of Kerala to document the species diversity and host range of soft scale insects. Soft scales were collected from agricultural, horticultural and forest ecosystems and road side avenue plants. Morphological characterization of the slide mounted female specimens revealed three species of Saissetiini *viz., Saissetia coffeae, S. oleae* and *Parasaissetia nigra*. The distribution and host range of the soft scale of Saissetini in Kerala are presented in this paper. The field diagnostic characters and taxonomic keys are provided for accurate identification of the species. The study reports a new distribution record of *S. oleae* from Kerala. Several new hosts are recorded for the soft scales, indicating their adaptability to a wider host range in the region.

Keywords: Coccids, soft scale, Saissetia, taxonomy, diversity, host range, distribution, Kerala

INTRODUCTION

The family Coccidae (Hemiptera: Coccidae), commonly known as soft scales, is one of the serious economic pests on agricultural, horticultural, and ornamental plants globally, with a wide distribution (Kondo and Watson, 2022). It is the third most species-rich family among Coccoidea (Henderson and Hodgson, 2005). Soft scale insects cause damage by sucking the sap which affects plant growth, leading to defoliation, withering of shoots/entire plant. The honeydew excreted coats the plant surface, which impedes assimilation and photosynthesis, and also acts as a perfect medium for sooty mould. Honeydew was also observed to attract ants, which potentially protected the pest from its natural enemies (Ben-Dov and Hodgson, 1997).

Hodgson (1994) revised the classification of soft scale insects based on the morphological characteristics of adult females and male since around 1960. He proposed a division of the family Coccidae into ten subfamilies, with the subfamily Coccinae further divided into four tribes including Saissetiini. According to the ScaleNet database, the tribe Saissetiini Hodgson, 1994 under the subfamily Coccinae, comprises approximately 148 species under 13 genera, distributed worldwide (Hodgson, 1994; García Morales *et al*., 2016). Although, the majority of Saissetiini species are primarily distributed in Neotropical and Ethiopian regions, several species exhibit cosmopolitan distribution and are recognised as economically important agricultural pests, such as *Parasaissetia nigra* (Nietner), *Parthenolecanium corni* (Bouché), *P. persicae* (Fabricius), and *Saissetia coffeae* (Walker) (Ben-Dov and Hodgson, 1997).

The genus *Saissetia* Deplanche comprises 46 known species worldwide, of which four species, *viz*., *S. coffeae, S. oleae, S. miranda* and *S. privigna* De Lotto have been documented from India (Ali, 1971; Shafee *et al*., 1989; Varshney, 1992; Hodgson, 1994; García Morales *et al*., 2016). *Saissetia coffeae* is a polyphagous pest that attacks coffee, tea, citrus and gauva (Le Pelley, 1968), ornamental plants, especially cycads and ferns (Ben-Dov, 1993) and pest of vegetable, fruit crops (Henderson *et al*., 2010). In India, *S. coffeae* is regarded as a pest of sandal trees, causing severe leaf and fruit fall in successive years until the tree dies (Sivaramakrishnan *et al*., 1987); it is also one of the main pests of coffee and cardamom (Narasimham, 1987). Waterhouse and Norris (1987) regarded *S. coffeae* as one of the main pests in the Pacific region. In California, it is a serious pest on ornamental plants, especially Boston fern (Gill, 1988; CABI, 2017). *S. oleae* is one of the most important pests of citrus in the Mediterranean Basin, Florida, California and South

America (Bartlett, 1978). Gill (1988) considered it to be the most injurious soft scale in California, and the most important pest of citrus there until 1940; he also reported it as a serious pest of olives. *S. privigna* De Lotto has been recorded on *Abelmoschus esculentus* (Varshney, 1992) and *Hibiscus rosa-sinensis* (Shafee *et al.,* 1989).

The genus *Parasaissetia,* includes five described species globally, with the majority occurring in the Ethiopian region (García Morales *et al*., 2016). Among them, only one species has been documented from India *i.e., Parasaissetia nigra* (Nietner) (Ali, 1971).This species is cosmopolitan in distribution and is considered as an occasional agricultural pest (Hamon and Williams, 1984). In this study, we re-describe and illustrate three species of the tribe Saissetiini from Kerala and their host associations.

MATERIALS AND METHODS

Purposive sampling surveys were conducted in different agricultural and horticultural ecosystems of Kerala during 2021-2025. Scale-infested plant parts *viz.,* leaves, stems, branches, twigs, fruits were cut with secateurs and collected in polythene bags. The samples were labelled with details such as locality, host plant, date of collection and GPS co-ordinates (using the mobile app, GPS Map Camera Lite) and brought to the Insect Systematics Laboratory. Photographs of the live specimens were captured under a stereo zoom microscope (ZEISS) attached with digital camera (Axiocam 208 color). Adult female scales were preserved in plastic vials containing 70% ethyl alcohol, furnished with accession numbers, for further processing. The preserved adult female coccid specimens were slide mounted following the techniques outlined by Hodgson and Henderson (2000). Morphological characterisation of the slide-mounted specimens were carried out by studying under a phase contrast microscope (RADICAL RXLr-4) and photomicrographs were captured using the ProCAM Multi Port 8MP HD camera with image analyzing software RADICAL attached to the microscope. Morphometry of the specimens was also made with the same software and are presented in micrometers (µm). The terminology used for describing both live and slide-mounted scales was adopted from Hodgson and Henderson (2000). All the studied specimens were deposited in the collection of the Insect Systematics Laboratory of the Department of Agricultural Entomology. A distribution map for the species of Saissetiini was prepared using Quantum GIS software 3.28 version.

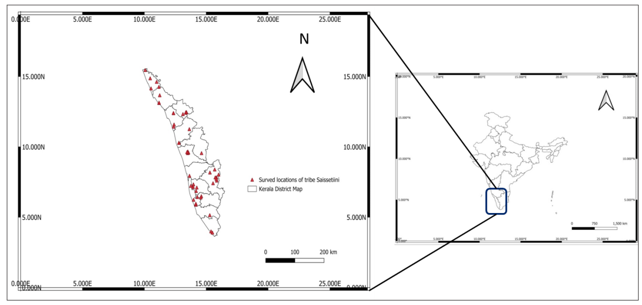

Fig. 1. Distribution of the tribe Saissetiini in Kerala, India

RESULTS AND DISCUSSION

This study reports three species of Saissetiini under two genera *viz.*, *Saissetia* and *Parasaissetia,* from different agroecosystems of Kerala state. The host plants and distribution details are provided in Table 1 and Figure 1.

Diagnostic characters of the tribe Saissetiini Hodgson

Dorsum typically convex and becomes heavily sclerotised with age, with distinct dermal aerolations. A broad submarginal band of ventral tubular ducts,

Table 1. Host association and distribution of Saissetiini in Kerala

Species	Host plant	Location (District & Locality)	GPS Co-ordinates in decimal degrees	
			Latitude (°N)	Longitude (°E)
Saissetia coffeae	*Tabernaemontana divaricata, Manilkara zapota, Psidium guajava, Coffeae arabica*	**Kasargod:** Nallompuzha, Padanakkad	12.3052 12.2636	75.3720 75.1273
	T. divaricata	**Kannur:** Kannothuchal	11.8847	75.3760
	Crossandra infundibuliformis, Ixora coccinea, Averrhoa carambola	**Kozhikode:** Kozhikode, Chelavoor	11.2438 11.3000	75.8266 75.8411

Saissetia coffeae	*C. arabica, Manilkara zapota, I. coccinea*	**Wayanad:** Edakkal, Ambalavayal, Maaniveyil	 11.6140 11.6278 11.5794	 76.2105 76.2064 76.1169
	Wrightia tinctoria	**Malappuram:** Tavanur	 10.8136	 75.9924
	T. coronaria, Gardenia jasminoides, Mangifera indica, Cycas revoluta, Plumeria alba, Coccinea grandis, Ficus hispida	**Thrissur:** Mannuthy, Vellanikkara, Villadam	 10.5355 10.5481 10.5621	 76.2639 76.2829 76.2434
	C. arabica	**Palakkad:** Nelliyampathy	 10.5353	 76.6930
	Citrus limon, Spathiphyllum wallisii	**Ernakulam:** Nettor	 9.9275	 76.3198
	M. indica, M. zapota, Pseuderanthemum carruthersii, C. grandis, Phaleria macrocarpa	**Alappuzha:** Krishnapuram, Haripad, Kayamkulam	 9.1485 9.2821 9.1766	 76.5145 76.4453 76.5178
	C. arabica, P. guajava, Gardenia jasminodes, I. coccinea, C. grandis, Ferula asafoetida, C. limon, Garcinia mangostana, Cestrum diurnum, Magnolia champaca, Zamia furfuraceae, Aristolochia indica, Aphanamimis polystachya	**Idukki:** Pampadumpara, Santhanpara, Myladumpara, Adimali, Munnar	 9.7985 9.9598 9.8857 10.0149 10.0960	 77.1644 77.2218 77.1560 76.9534 77.1015
	Abiu pouteria, Gardenia jasminodes, Psidium guajava, C. arabica	**Kottayam:** Thalayazham, Kumarakom, Kavanatinkara, Nattassery	 9.6966 9.6241 9.3715 9.6117	 76.44194 76.4275 76.2535 76.5458
	Abiu pouteria	**Pathanamthitta** Pullad	 9.3445	 76.6689
	C. arabica, Justicia adathoda	**Kollam:** Chingavanam, Punalur	 9.5188 8.8682	 76.5245 76.9491
Saissetia oleae	*M.indica, Nerium oleander*	**Kasargod:** Kolichal, Majarpalli	 12.4387 12.7529	 75.3008 74.9478
	Cnidoscolus acontifolius, Gliricidia sepium	**Kozhikode:** Peruvannamuzhi	 11.6032	 75.8244
	Morinda citrifolia	**Wayanad:** Manniveyil	 11.5794	 76.1169
	M. indica, Rollinia deliciosa, S. cumini	**Thrissur:** Mannuthy, Vellanikkara	 10.5355 10.5505	 76.2639 76.2828

Saissetia oleae	*M. zapota*	**Alappuzha:**		
		Krishnapuram	9.1485	76.5145
	M. zapota, Cycas revoluta	**Idukki:**		
		Maavadi,	9.8835	77.1190
		Murikkattukudy	9.7272	77.0499
	M. zapota	**Trivandrum:**		
		Balaramapuram	8.3990	77.0305
Parasaissetia nigra	*S. aquaeum*	**Kasargod:**		
		Chengala	12.5328	75.1014
	Hibiscus rosa-sinensis, Canna sp.,	**Kannur:**		
		Kannur,	11.8756	75.3766
		Panniyoor	12.0813	75.3974
	M. fragrans, S. aromaticum, Cnidoscolus acontifolius	**Kozhikode:**		
		Chelavoor,	11.3000	75.8411
		Peruvannamuzhi	11.6080	75.8223
	R. deliciosa	**Wayanad:**		
		Ambalavayal	11.6319	76.2258
	Myristica fragrans, Cnidoscolus acontifolius	**Malappuram:**		
		Kaalikavu	11.1773	76.3150
		Edappal	10.8098	75.9917
	Morinda citrifolia, Reulia tuberosa, M. fragrans, A. squamosa, Annona muricata, Alpinia purpurata, Blumea sp.	**Thrissur:**		
		Mannuthy,	10.5355	76.2639
		Madakkathara,	10.5505	76.2827
		Kannara,	10.5782	76.2666
		Chirakkaikode	10.5499	76.2883
	S. jambos, A.squamosa, M. zapota	**Alappuzha:**		
		Cherthala,	9.6566	76.3619
		Krishnapuram	9.1485	76.5145
	Terminalia catappa, Xanthostemon chrysanthus, H. rosa-sinensis, M. indica, Artocarpus heterophyllus	**Idukki:**		
		Nedukandem,	9.8433	77.1518
		Murikkattukudy,	9.7272	77.0499
		Santhanpara,	9.9598	77.2218
		Myladumpara	9.8857	77.1560
	H. rosa-sinensis, Myristica fragrans	**Kottayam:**		
		Kumarakom,	9.6241	76.4275
		Nattassery	9.6117	76.5458
	Manihot esculenta, S. samarangense	**Pathanamthitta**		
		Thiruvalla,	9.3566	76.5618
		Thadiyoor	9.3786	76.6874
	H. rosa-sinensis	**Kollam:**		
		Punalur	8.8682	76.9491
	S. cumini	**Trivandrum:**		
		Vellayani	8.4309	76.9871

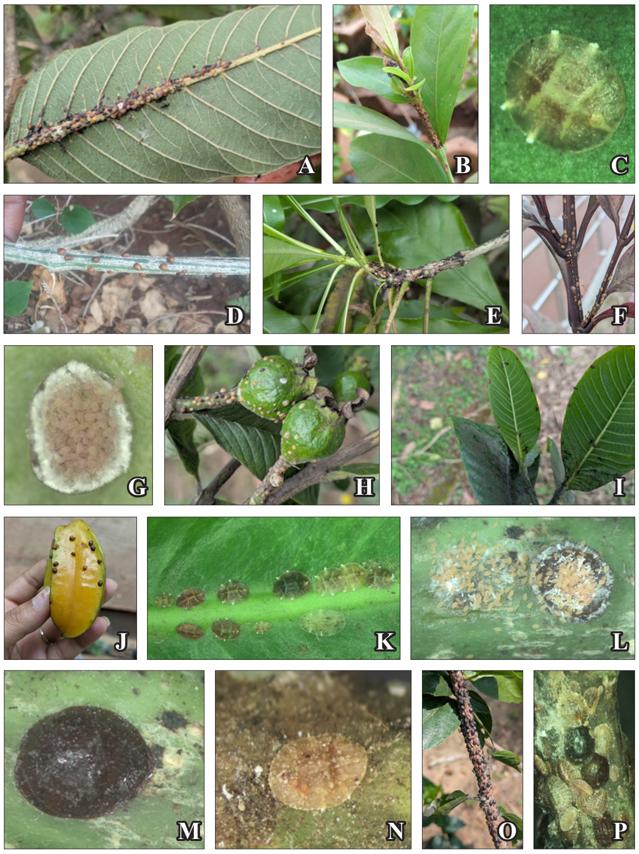

Fig. 2. Saissetiini (a-k, *Saissetia coffeae*) a. on guava congregated along the midrib of leaf, b. on shoot tip of *Ixora coccinea*, c. female with prominent 'H'-shaped ridge, d. on stem of ivy gourd, e. on the shoot of *Aristoalochia indica*, f. on the shoot of *Pseuderanthemum carruthersii*, g. mature adult female with eggs underneath body, h. on fruit & stalk of *Psidium guajava*, i. mature adult female below the leaf of *P. guajava*, j. on fruit of *Averrhoa carambola*, k. early instars congregated along the mid-vein; (l-n, *S. oleae*) l. mature adult female with eggs under the concave body, m. mature adult female dorsal view, n. early instar with white waxy granules on the body; (o-p, *Parasaissetia nigra*) o. congregation of scales along the shoot of hibiscus, p. colony of nymphs and adult females on the stem.

comprising one or two types present; dorsal tubular ducts absent. Eye spots near margin; dorsal submarginal tubercles and pocket like sclerotisations often present. Anal plate quadrate, with anterior margin never distinctly longer than posterior. Stigmatic cleft shallow, unsclerotised. Multilocular disc pores usually with 10 loculi, extending medially onto the thoracic region. Leg with or without tibio-tarsal sclerosis, claw without denticle; unsclerotised shallow stigmatic clefts, spiracle without sclerotic plate.

Key to genera of the tribe Saissetiini collected during the study

1a. Anal plate with discal setae (Fig. 4f); dorsal setae often spinose, with sharply pointed apices (Fig. 4h); leg with tibio-tarsal articulatory sclerosis (Fig. 3j); derm with distinct aerolations (Fig. 3f) .... ***Saissetia* Deplanche**

1b. Anal plate without discal setae (Fig. 5f); dorsal setae spinose, with clavate apices (Fig. 5g); leg without tibio-tarsal articulatory sclerosis; derm with numerous polygonal reticulations (Fig. 5e) .... ***Parasaissetia* Takahashi**

Genus: *Saissetia* Deplanche

Only two species were collected during the study *viz*., *S. coffeae* and *S. oleae.*

Key to the species of genus *Saissetia* Deplanche

1a. Anal plate without sclerosis around the margin (Fig. 3g); ventral tubular ducts of two types: type I -with broad inner ductule, present on medial sub marginal area and few ducts present around pro and meso coxa; type II -with broad narrow inner ductule, present on inner sub marginal area and medial area of thorax and abdomen (Fig. 3c) .... ***coffeae* Walker**

1b. Anal plate with sclerosis around the margin (Fig. 4e); tubular ducts of only one type, each with narrow inner ductule, present in sub marginal area (Fig. 4g) .... ***oleae* Olivier**

Saissetia coffeae Walker, 1852

Distribution: This species is cosmopolitan and a polyphagous pest on a wide range of ornamental plants. It has been documented from all zoogeographical regions (Zhang *et al*., 2018). It is particularly known as a pest of ornamental plants, with a notable preference for cycads (García Morales *et al*., 2016; Kondo and Watson, 2022; Paik, 1978; Kwon *et al*., 2005). In India, it has been reported from nearly all regions (Ali, 1968; Varshney, 1992).

Field characters: Adult females were broadly oval to nearly round and strongly convex. Mature adults were highly chitinised, with smooth, glossy brown coloured dorsal surface, typically with a layer of white silky wax protruding from beneath the abdomen, but not forming distinct ovisac (Fig. 2g). The integument was brown and sclerotized (Fig. 3a). The early developmental stages were yellowish and exhibited a characteristic 'H' shaped ridge on the dorsum (Fig. 2c), which became inconspicuous upon maturation (Fig. 3a). Adult female develops a concavity underneath the body, where light pinkish coloured eggs were laid (Fig. 2g). This species was generally found on the leaves (Fig. 2a, i), along vein (Fig. 2k), fruits, stalks (Fig. 2h, j), shoots (Fig. 2b, f) and stem (Fig. 2d, e) of the host plants.

Diagnostic characters: Dorsum: dorsal setae spine-like with pointed apices and distal end expanded, flat, and frayed; dermal aerolations more prominent with age (Fig. 3f); dorsal tubercles present; dorsal tubular ducts absent; anal plate quadrate (Fig. 3g), discal setae conspicuous with pointed or frayed apex; three apical setae, without subdiscal setae. **Margin:** setae bifid or fimbriate, with branched apices (Fig. 3d); three spiracular setae with middle one longer than lateral setae (Fig. 3e). **Venter:** antenna 8 segmented (Fig. 3h); multilocular disc-pores, mostly with 10 loculi, located near vulva and sparsely distributed on the meso-meta coxae (Fig. 3i); legs each with tibio-tarsal articulatory sclerosis (Fig. 3j); submarginal band of ventral tubular ducts with expanded filaments, scattered across venter (Fig. 3c).

Remarks: Commonly called the 'brown scale' or 'hemispherical scale' (BenDov, 1993). This species was collected on 27 plants belonging to 21 families. Tewlve new host plants are recorded for the species *viz., Crossandra infundibuliformis, Averrhoa carambola*, *Ficus hispida, Spathiphyllum wallisii, Phaleria macrocarpa, Ferula asafoetida, Garcinia mangostana, Magnolia champaca, Aphanamimis polystachya, Abiu pouteria, Wrightia tinctoria* and *Justicia adathoda*.

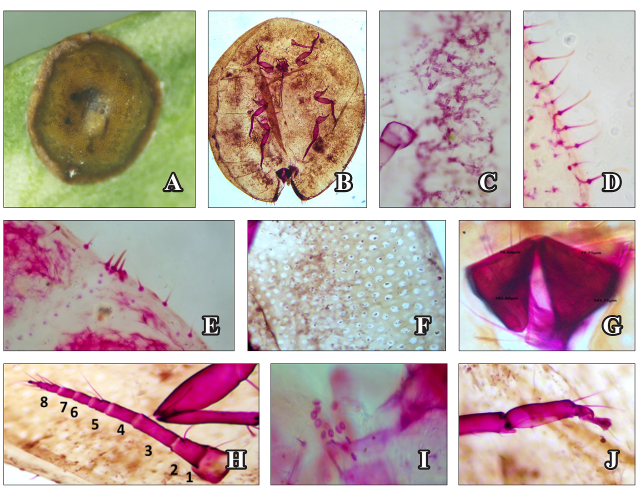

Fig. 3. ***Saissetia coffeae*** **Walker a. Adult female, b. Habitus, c. Submarginal tubular ducts, d. Marginal setae, e. Body derm, f. Anal plate, g. Antenna, h. Multilocular pores, i. Tibio-tarsal sclerosis**

4.1.2.1.2.1.2. *Saissetia oleae* Olivier, 1791

Distribution: *Saissetia oleae* is a cosmopolitan species with a wide distribution across all zoogeographical regions (Gill and Kosztarab, 1997; Kondo and Watson, 2022). It is a major pest of citrus, olive and ornamentals in many countries and Mediterranean region (Bodenheimer, 1951; Bartlett, 1978). It was also reported as a significant pest in Brazil (Ricalde *et al*., 2014), Argentina (Murua and Fidalgo, 2001), Peru (Lazo *et al*., 2008) and Uruguay (Vilamil and Albin, 2006).

Field characters: The body orange-yellow or grey in early stages, turning light brown or black colour on maturity (Fig. 2m). The dorsal surface rough, highly chitinized, and strongly convex. All developmental stages with a prominent median longitudinal ridge intersected by two transverse ridges, forming a characteristic "H"-shaped pattern (Fig. 2n). Small areas of clear, greyish to colourless wax granules were present on the dorsum (Fig. 4a). Adult female deposit eggs underside body (Fig. 2l). The scale was found infesting both leaves and shoots of host plants.

Diagnostic characters: Dorsum: dermal aerolations prominent in older females; dorsal setae pointed (Fig. 4h); anal plate quadrate with a sclerotized area surrounding them (Fig. 4e) and a conspicuous discal seta, but not fimbriate (Fig. 4f). **Margin**: Marginal setae pointed or with slightly fimbriate apices (Fig. 4c). **Venter**: Multilocular disc pores abundant around the vulvar area extending upto second abdominal segment, usually with 10 loculi; tubular ducts each with a narrow inner ductule restricted to the submarginal area (Fig. 4g); legs with tibio-tarsal articulation; antenna 8 segmented (Fig. 4d).

Remarks: Commonly called as 'black scale' or 'olive scale' (BenDov, 1993). This is the first report of the species from Kerala state. It was collected on nine plants belonging to nine families. *Cnidoscolus acontifolius, Gliricidia sepium, Morinda citrifolia, Rollinia deliciosa* and *Syzygium cumini* are documented as new host plants for this scale.

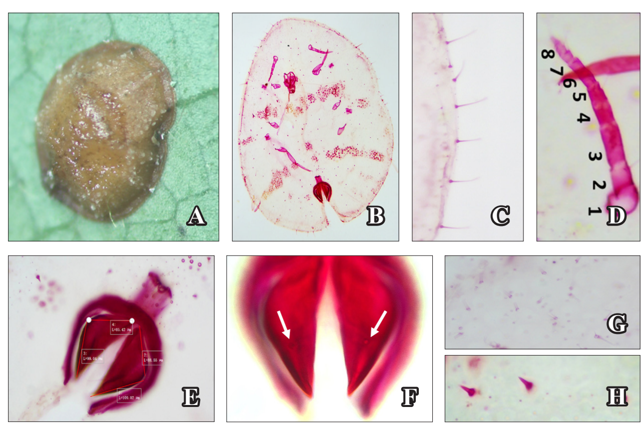

Fig. 4. ***Saissetia oleae*** **Olivier a. Adult female, b. Habitus, c. Marginal setae, d. Antenna, e. Anal plate, f. Discal setae, g. Tubular ducts, h. Dorsal setae**

4.1.2.1.2.2. Genus: *Parasaissetia* Takahashi

Only one species under the genus was collected during the study.

4.1.2.1.2.2.1. *Parasaissetia nigra* Nietner, 1861

Distribution: It was recognised as a cosmopolitan pest, reported from all zoogeographical regions and recorded on host plants belonging to over 100 families (García Morales *et al*., 2016; Gill and Kosztarab, 1997; Kondo and Watson, 2022). Waterhouse and Norris (1987) regarded *P. nigra* as a major crop pest in the Pacific region. This scale insect was reported on wide host range from different parts of India and also from Kerala (Ali, 1968; Kondo and Lin, 2022).

Field characters: Adult female typically convex and elongate to oval; body oval to almost circular, and colour varied depending on the host plant (Fig. 2o). Mature females were with brown or red mottling initially, later turned shiny dark brown, castaneous, or deep purple-black, and often darkening with age (Fig. 5a). The dorsum exhibited a slight median longitudinal carina and shallow lateral depressions, and was usually humped above the abdomen. At immature stages, body was less convex, elongate to narrow, translucent yellow, and mottled (Fig. 2p).

Diagnostic characters: Dorsum: Mature adult female derm with distinct polygonal reticulate pattern (Fig. 5e); dorsal setae often slightly capitate with clavate apices (Fig. 5g); dorsal tubular ducts absent; anal plate quadrate (Fig. 5f), each with four apical setae, but lacked discal setae; preopercular pores prominent anterior to anal plate. **Margin:** with slightly enlarged, fimbriate marginal setae (Fig. 5c). **Venter:** tubular ducts in asubmarginal band around the body margin, absent from median area of the venter (Fig. 5h); multilocular pores usually with 10 loculi, concentrated at the vulvar region; antennae 7 or 8 segmented (Fig. 5d), leg without tibio-tarsal sclerosis.

Remarks: Commonly called as 'hibiscus scale' or 'black scale' (Kondo and Lin, 2022). This specimen was collected on 22 plants belonging to 15 families. New host plants are recorded in the study *viz., Rollinia deliciosa, Reulia tuberosa, Annona squamosa* and the weed plant, *Blumea* sp.

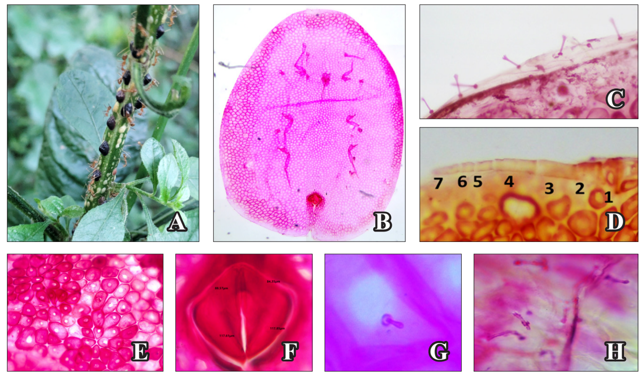

Fig. 5. ***Parasaissetia nigra*** **Nietner a. Adult female, b. Habitus, c. Marginal setae, d. Antenna, e. Body derm, f. Anal plate, g. Dorsal setae, h. Tubular ducts**

CONCLUSION

The present study documents distribution, and host range of three soft scale species of the tribe Saissetiini *viz*., *S. coffeae*, *S. oleae*, and *P. nigra* from Kerala. These species were found infesting a wide range of host plants across agricultural, horticultural, forest, and ruderal habitats, and several new host associations are recorded. The tribe Saissetiini possesses significant ecological adaptability and potential economic importance as polyphagous pest in tropical agroecosystems. The detailed morphological descriptions and key diagnostic characters presented in this study will aid in accurate identification and future taxonomic and ecological assessments. Several new hosts are recorded for the soft scales indicating their adaptability to wider host range in the region. In the changing climatic scenario, there is a chance that these scale insects further expand their host range and turn invasive, posing threat to agroecosystems.

ACKNOWLEDGEMENTS

All authors are thankful to Kerala Agricultural University for research funds and ICAR- National Bureau of Agricultural Insect Resources (NBAIR), Bengaluru for providing facilities for the conduct of the study.

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MS Received: 28 May 2025
MS Acceptance: 10 June 2025

Pest Management in Horticultural Ecosystems
Vol. 31, No.1 pp 10-15 (2025) DOI Number :

Evaluation of mango varieties against fruit borer, *Citripestis eutraphera* (Meyrick) under humid tropics in Gujarat, India

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ABSTRACT: Evaluation of 12 mango varieties/hybrids was carried out against the mango fruit borer, *Citripestis eutraphera* (Meyrick), (Lepidoptera: Pyralidae) at Agriculture Experimental Station, Navsari Agriculture University, Paria, Gujarat during two consecutive years (2022 and 2023). Pooled results showed that mango varieties Ratna, Totapuri Neelam, Vellaikolamban, Neeleshan and Vanraj were proved least preferred by the fruit borer recording lowest fruit borer infestation (2 to 5 % and 13 to 15% on standing tree and dropped fruits under tree, respectively) followed by Dashehari, Amrapali and Sonpari which recorded 4.65, 5.76, 5.39 per cent and 23.17, 24.28, 22.93 per cent fruit borer infestation in terms of standing tree and dropped fruits under tree, respectively. Whereas Alphonso and Kesar were most preferred varieties by fruit borer recording 9.28 and 7.08 per cent infestation on standing tree and 31.12 and 24.99 per cent dropped fruits infestation under tree, respectively. The overall highest damage intensity was found during first fortnight of May in most of the varieties.

Keywords: Mango, fruit borer, *Citripestis eutraphera*, varietal screening.

INTRODUCTION

Mango, *Mangifera indica* L. (Family: Anacardiaceae), is a tropical and subtropical fruit known as "King of Fruits". The states of Andhra Pradesh, Uttar Pradesh, Karnataka, Bihar, Gujarat and Maharashtra are major mango producers of the country. In Gujarat, Valsad, Navsari, Gir Somnath, Kutch and Surat are the major mango producing districts. Valsad and Navsari are major mango producing districts of South Gujarat having sub-tropical climate with moderately high humidity. In mango, about 492 species of insects, 17 species of mites and 26 species of nematodes have been reported from all over the world (Tandon and Verghese, 1985). Of these, 188 species have been reported from India (Butani, 1978; Tandon and Verghese, 1985) but only handfuls are of major importance which includes hopper, thrips, mealy bugs, stem borer, fruit flies and stone weevil. Some of the minor pests were also found to become major pests as a result of the changes in the environment. Prior to recent time, minor or secondary pests such as scales, thrips, mites, leaf webbers, stem borers, fruit borers, *etc*., are considered to be a threat (Jayanthi *et al.,* 2014). The mango fruit borer, *Citripestis eutraphera* (Meyrick), (Lepidoptera: Pyralidae) originally confined to the Andaman Islands, is a recent invasion in mainland India. Mango fruit borer, *C. eutraphera* which was originally described from Java, is a significant borer of mango fruits in South and South-East Asia and some parts of Australia (Anderson and Tran-Nguyen, 2012).

The most recent classical example of intra-national invasion of insect pests from the Andaman and Nicobar Islands to mainland India is the mango fruit borer, *C. eutraphera* and it was probably restricted to the Islands for almost two decades, till 2014, when it was reported by Jayanthi *et al.* (2014) from South India on mango. They first time reported the occurrence of *C. eutraphera* causing extensive damage to immature fruits of mango in Karnataka and Tamil Nadu. The infestation of *C. eutraphera* was recently reported for the first time in Gujarat, where it caused significant damage (Bana *et al.,* 2018). This species recently invaded and spread to mainland India and infested mango in Karnataka, Tamil Nadu, Kerala, Gujarat, parts of Maharashtra and Odisha (Krull and Basedow, 2006; Krull, 2004; Jayanthi *et al.,* 2014; Hiremath *et al.,* 2017; Singh and Kaur, 2014; Sunitha *et al.,* 2020) and recently in Punjab (Singh *et al.,* 2021). Mango-growing pockets in the South-Western parts of Gujarat, as well as parts of Kerala and Tamil Nadu will remain moderately to highly suitable for *C. eutraphera* distribution in 2050 and 2070 (Choudhary *et al.,* 2019).

Resistant varieties play a vital role in integrated pest management (IPM) by reducing the insecticidal application against insect pests and improving the performance of natural enemies. The low level of resistance is also effective, which helps in reducing the insecticidal load on crops and ultimately the cost of cultivation (Srivastava, 1993). Insect-resistant varieties provide pest control at no cost to farmers (Prem Kishore, 2001). Therefore, it is important to identify the resistance genotypes or varieties. A study on resistance mechanisms in relation to crop phenological stages is essential for the crop improvement program in effective utilization of resistant sources. So, the use of resistant varieties is an environmentally safe and economically sound component of Integrated Pest Management (IPM). By considering this, evaluation of mango varieties against infestation of fruit borer,*C. eutraphera*was carried out to strengthen the IPM practices.

MATERIALS AND METHODS

The evaluation of mango varieties against fruit borer *C. eutraphera* was carried out under field conditions at Agriculture Experimental Station, NAU, Paria, Gujarat ($20^0$26'58.427"N $72^0$57'5.723"E) during 2022 and 2023. All the recommended agronomical practices of NAU, Navsari were followed. A total of 12 varieties *viz*., Alphonso, Amrapali, Ratna, Neeleshan, Kesar, Totapuri, Neelam, Vanraj, Dashehari, Sonpari, Karanjio and Vellaikolamban were screened in Randomized Block Design (RBD) with three replications. Three trees (one tree considered as one replication) from each of the selected varieties with 8m x 8m spacing were observed at weekly interval. The selected trees were kept free from insecticidal spray throughout the experimental period. The clearly visible 25 fruits/tree from the ground in all directions were observed for infestation of fruit borer starting from the fruit growth of marble size to the harvesting of fruits and per cent infestation was worked out. Total number of dropped fruits under tree were recorded from which fruit borer infested fruits were separated and per cent infestation was worked out.

RESULTS AND DISCUSSION

The newly emerged larvae of *C. eutraphera* scraped the fruit's skin on upper 1/3 portion of fruit and also the peduncle when single fruit was infested (Fig.1-b), whereas when multiple fruits (two or more) are infested, larvae scraped the fruit's skin at jointed portion (Fig.1-i). The late instars bore holes in the fruit to feed on the pulp to reach the soft seed/ kernel (Fig 3-e). In infested fruits, bored holes filled with frass (Fig. 1-h) and adjacent fruits of mango were often found blackened around the bored area (Fig. 1-i). During marble to egg stage, early instar larva also started feeding on the peduncle (Fig.1-b,c). resulted in premature dropping of fruits (Fig.1-l). The sap stain running from bore hole made by the larvae (Fig.1-g). The larva created irregular galleries in the kernel and completely devoured it. The infected kernel lost the germination. The exit hole allows ants, beetles, and occasionally microorganisms to enter the fruits. Furthermore, the damage caused longitudinal cracks in the fruits, which encouraged fruit flies to lay their eggs there (Fig.1-f).

The data on per cent fruit borer infestation on standing tree and per cent infestation in terms of dropped fruit under tree from marble stage to mature are presented in Table 1 and 2, respectively. Among all the varieties tested, Vellaikolamban is early variety; Alphonso, Kesar, Dashehari, Karanjio and Vanraj are the mid varieties; Sonpari is the mid-late variety; whereas Amrapali, Totapuri, Ratna, Neelam and Neeleshan are late varieties.

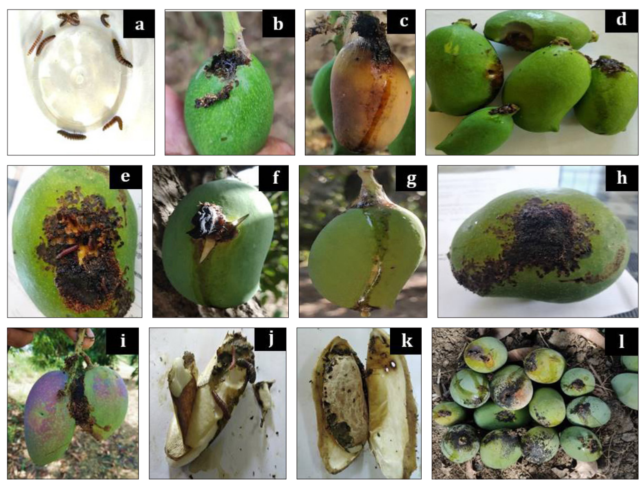

Fig.1: Damage by *C. eutraphera*: Larvae-a; Damage at marble stage-b (Fruit skin scraped by early instar larva); Rotting of fruit-c; Damage at egg size stage-d; Damage at mature stage-e; Cracking of fruits due to infstation-f; Sap stain running from bore hole-g; Entry hole plugged with excreta-h; Damage at jointed fruits-i: Larva feed on the soft kernal of mango-j & k; mature fruits dropped due to infestation-l.

Infestation on Standing Tree

Results revealed that all the varieties showed more or less fruit borer infestation during the season and it was commenced from first week of March (10^{th} SMW) coincided with the marble stage continued up to first week of June (22th SMW) coincided with the mature

Table 1: Screening of mango varieties against mango fruit borer in terms of per cent infested fruits on standing tree (Pooled of two years)

SN	Variety	Fruit borer infestation (%)												
		10thSMW	11thSMW	12thSMW	13thSMW	14thSMW	15thSMW	16thSMW	17thSMW	18thSMW	19thSMW	20thSMW	21stSMW	22ndSMW	Pooled
1	Alphonso	10.85 (3.57)	11.79 (4.21)	13.28 (5.31)	16.23 (7.82)	18.82 (10.42)	19.46 (11.11)	20.72 (12.54)	22.39 (14.56)	23.04 (15.40)	23.06 (12.45)	18.58 (10.18)	15.93 (7.61)	13.28 (5.41)	17.74 a (9.28)
2	Kesar	7.55 (1.73)	8.72 (2.32)	12.81 (4.94)	14.49 (6.27)	16.58 (8.15)	17.82 (9.41)	19.31 (10.96)	20.32 (12.13)	19.70 (11.39)	19.71 (9.02)	15.13 (6.85)	12.36 (4.71)	11.65 (4.11)	15.43 g (7.08)
3	Dashehari	4.97 (0.76)	6.45 (1.27)	10.28 (3.21)	10.38 (3.27)	12.68 (4.84)	14.31 (6.15)	15.29 (7.02)	15.75 (7.45)	16.16 (7.87)	16.26 (6.09)	12.29 (4.57)	12.62 (4.84)	10.09 (3.09)	12.45 e (4.65)
4	Amrapali	8.41 (2.15)	6.87 (1.46)	11.76 (4.19)	12.36 (4.60)	14.61 (6.37)	15.92 (7.54)	16.87 (8.46)	18.41 (10.09)	18.34 (9.93)	18.34 (7.85)	14.09 (6.08)	11.26 (3.93)	8.57 (2.23)	13.89 f (5.76)
5	Totapuri	0.00 (0.00)	0.00 (0.71)	6.87 (1.46)	8.62 (2.26)	8.81 (2.37)	10.60 (3.47)	11.11 (3.72)	12.86 (5.00)	13.31 (5.40)	13.27 (4.05)	9.83 (2.98)	8.03 (1.98)	4.83 (0.74)	9.33 a (2.63)
6	Sonpari	6.55 (1.31)	7.55 (1.74)	10.49 (3.35)	10.64 (3.44)	13.45 (5.44)	16.77 (8.36)	17.15 (8.73)	18.03 (9.64)	17.53 (9.10)	17.56 (7.82)	15.08 (5.87)	10.27 (3.19)	8.11 (2.08)	13.42 f (5.39)
7	Ratna	5.52 (0.94)	4.52 (0.66)	7.34 (1.65)	8.38 (2.13)	8.60 (2.25)	10.73 (3.59)	11.20 (3.78)	11.80 (4.36)	12.32 (4.65)	12.39 (3.02)	8.57 (2.63)	6.22 (1.19)	4.83 (0.74)	8.97 a (2.43)
8	Neelam	0.00 (0.00)	4.81 (0.73)	6.43 (1.26)	9.70 (2.88)	9.08 (2.52)	10.95 (3.68)	12.76 (4.90)	14.22 (6.12)	14.77 (6.52)	14.75 (4.14)	10.11 (3.18)	8.35 (2.11)	8.71 (2.31)	10.14 b (3.10)
9	Karanjio	5.10 (0.81)	8.92 (2.44)	10.64 (3.44)	13.87 (5.78)	15.25 (6.95)	17.00 (8.62)	18.17 (9.77)	19.10 (10.74)	18.32 (9.90)	18.28 (7.09)	13.59 (5.55)	10.05 (3.14)	7.38 (1.73)	13.98 f (5.84)
10	Neeleshan	0.00 (0.00)	3.85 (0.46)	7.68 (1.79)	9.60 (2.81)	10.55 (3.38)	12.17 (4.48)	14.40 (6.26)	16.22 (8.18)	17.04 (8.61)	17.00 (6.87)	13.01 (5.10)	9.91 (3.15)	9.33 (2.67)	11.74 d (4.14)
11	Vanraj	0.00 (0.00)	3.86 (0.47)	7.69 (1.80)	9.67 (2.86)	10.43 (3.31)	12.87 (5.01)	13.10 (5.26)	15.12 (6.98)	15.79 (7.51)	15.89 (8.33)	13.99 (5.94)	10.36 (3.26)	10.91 (3.61)	11.80 d (4.18)
12	Vellaikolamban	0.00 (0.00)	0.00 (0.00)	7.24 (1.61)	8.26 (2.07)	11.15 (3.75)	12.78 (4.91)	14.07 (6.02)	15.59 (7.36)	16.23 (7.94)	16.34 (6.21)	10.90 (3.69)	8.21 (2.04)	8.63 (2.27)	11.06 c (3.68)
	S.Em. ±	0.34	0.58	0.59	0.54	0.58	0.79	0.81	1.24	0.88	0.82	0.98	1.02	0.77	0.20
	CD (5 %)	0.99	1.70	1.75	1.60	1.73	2.32	2.38	3.65	2.58	2.42	2.91	3.01	2.28	0.57
	CV %	14.21	17.79	10.92	8.53	8.10	9.54	9.09	12.87	8.98	8.42	13.18	17.17	15.13	6.45

Figures in parenthesis are original values and those outside are arcsine transformed values. Treatment means followed by the same latter(s) within a column are not significantly different by Duncan's New Multiple Range Test (DNMRT at 5% level of significance.

stage or harvesting stage. Moreover, peak infestation was recorded mostly during last week of April to first week of May (17th& 18th SMW) coinciding with egg size stage. The lower fruit borer infestation was noticed during early fruit development stages.

The data showed that, during early fruit development stage (10th SMW), infestation of *C. eutraphera* was not commenced simultaneously in all the varieties. The varieties *viz*., Vanraj, Vellaikolamban, Neeleshan, Neelam and Totapuri was found free from infestation. Pooled results showed that the difference in fruit borer infestation in all the varieties was found significant. Significantly lowest fruit borer infestation was recorded in Ratna (2.43 %) which was statistically at par with Totapuri (2.63 %) and Neelam (3. 10%).The next best varieties in term of lower fruit borer infestation were Vellaikolamban (3.68 %), Neeleshan (4.14 %), Vanraj (4.18 %) and Dashehari (4.65 %) which were not differ statistically from each other. Moderate infestation was noticed in Amrapali (5.76 %) and Sonpari (5.39 %). Significantly highest infestation was noted in Alphonso variety (9.28 %) followed by Kesar (7.08 %) (Table 1).The damage intensity was reached highest during first fortnight of May in Alphonso (7.87 %), Dashehari (15.40%), Totapuri (5.40%), Sonpari (9.10%), Ratna (4.65%), Neelam (6.22%), Neeleshan (8.61%), Vanraj (8.33%), Vellaikolamban (7.94%) and second fortnight of April in Kesar (12.13%), Amrapali (10.09%), and Karanjio (10.74%) (Table 1).

Infestation in terms of dropped fruits under tree

All the varieties showed more or less fruit borer infestation during the season and it was commenced from first week of March (10th SMW) continued up to first week of June (22th SMW). Moreover, peak infestation was recorded mostly during last week of April to first week of May (17th& 18th SMW) coinciding with egg stage. The lower fruit borer infestation was noticed during early fruit development stages.

The data showed that, during early fruit development stage (10th SMW), infestation of *C. eutraphera* was

Table 2. Screening of mango varieties against mango fruit borer in terms of per cent infested dropped fruits under tree (Pooled of two years)

S.N	Variety	Fruit borer infestation (%)													
		10thSMW	11thSMW	12thSMW	13thSMW	14thSMW	15thSMW	16thSMW	17thSMW	18thSMW	19thSMW	20thSMW	21stSMW	22ndSMW	Pooled
1	Alphonso	4.25 (19.81)	4.86 (23.17)	4.99 (25.24)	5.16 (26.59)	4.90 (24.01)	5.26 (27.48)	5.50 (30.70)	5.81 (33.32)	5.92 (34.62)	6.15 (37.45)	6.45 (41.41)	6.67 (44.02)	6.05 (36.68)	5.62 e (31.12)
2	Kesar	2.60 (8.10)	3.86 (14.95)	4.61 (20.91)	4.62 (21.04)	4.46 (19.48)	4.58 (20.54)	4.93 (24.09)	5.66 (31.89)	5.63 (31.31)	5.72 (32.28)	5.67 (31.72)	6.01 (36.09)	5.74 (32.48)	5.04 d (24.99)
3	Dashehari	1.67 (4.17)	3.88 (15.00)	4.04 (16.04)	4.86 (23.28)	4.35 (18.65)	4.37 (19.10)	4.89 (24.02)	5.51 (30.06)	5.47 (29.62)	5.52 (30.91)	5.45 (29.37)	5.55 (30.42)	5.54 (30.55)	4.86 d (23.17)
4	Amrapali	0.71 (0.00)	4.07 (16.34)	4.55 (20.50)	4.96 (24.11)	4.59 (20.59)	4.40 (19.40)	5.00 (24.65)	5.33 (28.11)	5.39 (28.98)	5.67 (32.12)	5.89 (34.93)	6.07 (36.98)	5.42 (28.94)	4.96 d (24.28)
5	Totapuri	0.71 (0.00)	2.43 (6.94)	2.81 (7.43)	3.83 (15.12)	3.61 (13.18)	3.96 (15.35)	3.96 (15.60)	4.33 (18.28)	4.63 (21.18)	4.53 (20.16)	4.69 (21.60)	5.19 (26.65)	4.95 (24.72)	4.04 bc (15.86)
6	Sonpari	1.85 (5.56)	3.60 (12.59)	4.10 (16.80)	4.34 (18.49)	4.48 (19.90)	4.22 (18.14)	4.71 (22.56)	5.43 (29.32)	5.50 (29.83)	5.68 (31.83)	5.80 (33.27)	5.67 (32.26)	5.26 (27.60)	4.84 d (22.93)
7	Ratna	0.71 (0.00)	2.52 (7.50)	2.95 (8.52)	2.61 (6.54)	2.67 (7.15)	3.21 (9.91)	2.98 (8.47)	3.68 (13.29)	3.98 (15.42)	3.91 (14.95)	4.03 (15.77)	4.01 (17.09)	3.78 (14.35)	3.34 a (10.69)
8	Neelam	0.71 (0.00)	1.98 (6.67)	3.26 (10.56)	3.33 (10.97)	3.40 (11.71)	3.32 (11.07)	3.16 (9.81)	4.04 (16.39)	4.30 (18.20)	4.42 (19.31)	4.35 (18.64)	4.79 (23.03)	3.90 (15.20)	3.70 ab (13.20)
9	Karanjio	0.71 (0.00)	2.52 (7.50)	3.45 (11.85)	3.94 (15.31)	3.74 (13.65)	3.74 (13.78)	4.87 (23.46)	4.99 (24.51)	5.49 (29.99)	5.59 (31.52)	5.64 (31.99)	5.70 (32.61)	5.40 (29.94)	4.56 cd (20.47)
10	Neeleshan	0.71 (0.00)	2.52 (7.50)	3.36 (10.87)	3.79 (13.87)	3.63 (12.81)	3.53 (11.98)	3.44 (11.98)	3.95 (15.10)	4.43 (20.10)	4.45 (20.15)	4.89 (23.70)	5.01 (25.15)	4.23 (17.63)	3.88 b (14.68)
11	Vanraj	0.71 (0.00)	2.40 (6.67)	2.85 (7.70)	2.94 (8.37)	2.79 (7.46)	3.39 (11.18)	2.87 (8.20)	4.44 (19.31)	4.59 (20.82)	4.88 (23.32)	4.81 (22.68)	4.27 (17.98)	3.72 (13.89)	3.66 ab (12.89)
12	Vellaikolamban	1.61 (3.70)	2.22 (5.59)	2.81 (7.43)	3.24 (10.37)	2.98 (8.68)	3.28 (10.55)	3.01 (8.71)	4.16 (16.89)	4.47 (20.11)	4.75 (22.76)	4.91 (23.89)	4.55 (21.00)	4.25 (17.72)	3.75 ab (13.65)
	S.Em. ±	0.65	0.76	0.37	0.38	0.40	0.40	0.46	0.31	0.38	0.43	0.35	0.51	0.47	0.18
	CD (5 %)	1.91	NS	1.09	1.10	1.17	1.17	1.35	0.90	1.10	1.27	1.03	1.50	1.38	0.52
	CV %	80.16	42.70	17.70	16.41	18.26	17.59	19.50	11.15	13.10	14.73	11.74	16.80	16.90	7.04

Figures in parenthesis are original values and those outside are arcsine transformed values. Treatment means followed by the same latter(s) within a column are not significantly different by Duncan's New Multiple Range Test (DNMRT) at 5% level of significance.

commenced in almost all the commercial varieties *viz*., Vanraj, Vellaikolamban, Neeleshan, Neelam, Ratna, Karanjio and Amrapali was found free from infestation. Pooled results showed that the difference in fruit borer infestation in all the varieties was found significant. Significantly lowest fruit borer infestation was recorded in Ratna (10.69%) which was statistically at par with Vanraj (12.89%), Neelam (13.20%) and Vellaikolamban (24.28%). The next best varieties in term of lower fruit borer infestation dropped under tree were Neeleshan (14.68%) and Totapuri (15.86%) which were not differ statistically from each other. Significantly highest infestation was noted in Alphonso variety (31.12%) which was not differing statistically from Kesar (24.99%), Amrapali (24.28%), Dashehari (23.17%) and Sonpari (22.93%).

It was also noticed that, the varieties with bunch bearing character were found most susceptible to fruit borer infestation. Dashehari and Amrapali were the bunch bearing mango varieties hence found susceptible. From the results it also can be conclude that most of the mid varieties were susceptible to fruit borer infestation however, early and late varieties were least susceptible. Even though Amrapali were late variety, but due to bunch bearing character it was found susceptible to *C. eutraphera*.

Perusal of literature revealed that, very few and scanty reports are available so far pertaining to the screening of mango varieties against *C. eutraphera*. Bhattacharyya (2014) tested susceptibility of fifteen commercially grown mango cultivars against *C. eutraphera* and concluded that Himsagar, Arka Anmol, Prabha Sankhar and Amrapali were the most susceptible varieties. In present study, Amrapali was also found susceptible to *C. eutraphera*. Thus confirms the present finding. According to Dulai *et al*. (2015) average infestations of fruit borer in commercial varieties are always higher than the infestations in folk varieties. Alphonso, Kesar, Dashehari and Amrapali are the commercial varieties tested during present study and found susceptible. Thus, present findings are in line with earlier workers.

Besides mango, it also infested seedlings and grafts of cashew, *A. occidentale* in Kerala (Jacob *et al.,* 2004; Hiremath *et al.,* 2017; Kori Nagaraj *et al.,* 2020, Kori Nagaraj *et al.,* 2022). Reddy *et al.* (2022) screened fifty-two released cashew varieties against *C. eutraphera* and concluded that none of the released cashew varieties showed either tolerance /resistance to attack of *C. eutraphera*, indicating no varietal preference for infestation.

ACKNOWLEDGEMENT

Authors acknowledge the support of Director of Research, Navsari Agricultural University, Navsari and Research Scientist (Horticulture), Agriculture Experimental Station, NAU, Paria for providing the necessary research facilities.

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MS Received: 24 April 2025
MS Acceptance: 21 May 2025

Pest Management in Horticultural Ecosystems
Vol. 31, No.1 pp 16-23 (2025)
DOI Number : 10.5958/0974-4541.2025.00003.0

Population dynamics of major insect pests of cashew and their associated natural enemies

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ABSTRACT: Studies on the population dynamics of major insect pests of cashew and their associated natural enemies were conducted during 2021-22 at Zonal Agricultural and Horticultural Research Station (ZAHRS), Shivamogga, Karnataka, India. During the study, leaf miner, *Acrocercops syngramma* Meyrick, tea mosquito bug, *Helopeltis* spp. and thrips, *Scirtothrips dorsalis* Hood were found to be major pests. Leaf miner was predominant with a peak population of 4.54 larvae per 20 leaves during fourth week of November with highest per cent leaf incidence of 22.70. Tea mosquito bug was found at new flushing and panicle stage with peak activity during second week of December with 6.50 bugs per 20 shoots with peak per cent incidence of 32.75. Thrips occurred both at panicle and nut stage with peak population during third week of February (6.70/20 panicles) and peak per cent incidence on nut surface during first week of April (33.75 %). There was a positive correlation of leaf miner and tea mosquito bug with minimum temperature, morning relative humidity, evening relative humidity, sunshine hours and negative correlation with maximum temperature and rainfall, whereas thrips showed positive correlation with maximum temperature, sunshine hours and negative correlation with rainfall, minimum temperature, morning relative humidity and evening relative humidity at ZAHRS, Shivamogga. The natural enemies on insect pests of cashew included predators *viz*., mantidflies, *Coccinella transversalis* (Fabricius), *Chrysoperla* sp., red ants, *Oecophylla* sp. and hover flies, *Ischiodon scutellaris* (Fabricius).

Keywords: Cashew, leaf miner, tea mosquito bug, thrips, natural enemies

INTRODUCTION

Cashew, *Anacardium occidentale* L., a native of Brazil, was introduced to India by Portuguese travelers during the 16th century for afforestation and soil conservation purposes. In India, cashew is cultivated in an area of 10.62 lakh hectares with a total production of 6.91 lakh tonnes with a productivity of 706 kg/ha during 2020-21. In Karnataka, cashew is cultivated in an area of 1.26 lakh hectares with a total production of 0.53 lakh tonnes with a productivity of 461 kg/ha during 2020-21 (Anonymous, 2020). Cashew production is affected by various biotic and abiotic factors. Among the biotic factors, the insect pests are one of the major limiting factors causing a crop loss of about 30 to 40 per cent. More than 180 insect pests attack cashew, of which cashew leaf miner is of considerable importance (Beevi *et al*., 1993). Cashew is attacked by more than one species of insects, mites and vertebrates in India, among which the cashew stem and root borer (CSRB), tea mosquito bug (TMB) and foliage and flower insects (like thrips, leaf caterpillar and leaf miner) are important limiting factors (Sundararaju, 1993b). Many insect pests and their natural enemies are found in cashew crops. Among which, the main pests are *Helopeltis antonii* Signoret, *Plocaederus ferrugineus* L. and considerable damage was also caused by *Scirtothrips dorsalis* Hood, *A. syngramma* Meyrick, *Hypatima haligramma* Meyrick, *Lamida moncusalis* Walker and *Thylacoptila paurosema* Meyrick. *H. antonii* is preyed by five species of spiders and a cocinellid. Larvae of *A. syngramma* are parasitized by the Eulophid and *Sympiesis* sp. (Sundararaju, 1993a). In this view, the study was conducted to record the major insect pests of cashew and their associated natural enemies.

MATERIALS AND METHODS

Experiment was conducted at Agricultural and Horticultural Research Station (AHRS), Bavikere and Zonal Agricultural and Horticultural Research Station (ZAHRS), Shivamogga. Observations on seasonal incidence on major insect pests of cashew were carried out throughout the year. Observations on cashew pests and its natural enemies were recorded at weekly intervals by selecting five seedlings in nursery and five trees in the main field randomly. A well maintained 15 years old plantation was used for studying population dynamics of major insect pests of cashew. In nursery, in each seedling, five leaves were observed for leaf miner larvae and mean number of larvae per plant was calculated. The data were subjected to suitable statistical analysis and correlated with the weather parameters following the methods of Gomez and Gomez (1984). In cashew orchard, observations on leaf miner larvae were recorded by selecting four branches in each tree bearing new flushes covering all the four directions. From each newly flush bearing branch, five leaves from each side, totally 20 leaves were selected for counting the leaf miner larvae. Per cent infestation was worked out by using formula, Infestation (%) = Number of infested leaves/ Total no. of observed leaves×100. Observations on tea mosquito bug was recorded by selecting five shoots in each tree from each direction and totally 20 shoots from four directions per tree were selected to record TMB damage (in total 100 shoots from five trees). The per cent incidence was worked out by using the formula, Per cent incidence = Sum of all numerical ratings/No. of shoots observed×maximum rating×100. Infestation of thrips was recorded during nut stage on the panicle and nut surface. In each tree, 20 panicles and 20 fruits were selected randomly (in total 100 nuts and 100 panicles from five trees). Mean number of thrips per panicle was recorded and per cent incidence, based on the nut surface damaged, was recorded by using the formula, Per cent Nut surface Damaged = Sum of numerical scoring/ Maximum scoring×Number of nuts observed×100. Natural enemies were collected from affected insect stages from cashew nursery and field.

RESULTS AND DISCUSSION

During the study period, 22 species of insect pests were found infesting cashew plantation (Table 1). Among these, leaf miner, *Acrocercops syngramma* (Meyrick), tea mosquito bug, *Helopeltis* spp. and thrips, *Scirtothrips dorsalis* Hood (Plate 1, 2 and 3) were found as major insect pests of cashew. The mean of weekly observations on incidence and per cent infestation of leaf miner, tea mosquito bug and thrips were recorded on cashew at College of Agriculture, Shivamogga during 2021-2022 and presented in Table 2. The leaf miner incidence mainly occurred in new flush stage of cashew from October, 2021 to February, 2022 and reached its peak with 4.54 larvae/20 leaves in fourth week of November. Peak per cent incidence of leaf miner was found during the fourth week of November (22.70) and minimum per cent incidence was noticed during the third week of February (1.30). These findings are in close agreement with Rao *et al*. (2006) who reported that the leaf miner (*A. syngrammma*) incidence was at its peak during the second week of December with nil infestation during May-June and lowest incidence during July. This is also in agreement with Athalye and Pati1 (1999) who reported that the incidence of the cashew leaf miner was found throughout the year in Maharashtra with peak incidence (18.21 %) during September on post monsoon vegetative flush. The TMB incidence occurred both at new flushing and panicle stage of cashew from October, 2021 to February, 2022 and peak activity was found during second week of December with 6.50 bugs per 20 shoots. Maximum per cent incidence of TMB was noticed during second week of December (32.75) and minimum per cent incidence was recorded during second week of February (4.50). This finding is in close line with the findings of Vidya *et al*. (2015) who reported that TMB was abundant during flushing to fruiting stage of the cashew. Sathapathy (1993) also reported the peak incidence of TMB during January with shoot and panicle damage with the 42.80 and 19.20 per cent, respectively which is also in line with present research findings. The prevalence of thrips occurred both in panicle and nut stage of cashew during December, 2021 to May, 2022 and peak population was found during third week of February with 6.70 thrips/20 panicles. Peak per cent incidence of thrips was noticed during first week of April (33.75) and minimum per cent incidence was recorded during second week of February (1.75). These findings are in line with Sundararaju (1984) who noticed the peak incidence of thrips during December to February in Goa. The leaf miner incidence was studied in nursery stage of cashew during 2021 at AHRS, Bavikere and it was represented in table 3. Peak population of 4.13 larvae was recorded during the third week of November with peak per cent incidence of 16.50. Minimum population was recorded during first week of October with 0.91 larvae per 25 leaves with least per cent incidence of 3.64. These results are in close line with Sundararaju (1984) who reported that leaf miner incidence started during July and reached its peak by November to December. The incidence of major insect pests of cashew were correlated with various weather parameters *viz*., maximum temperature, minimum temperature, morning relative humidity, evening relative humidity, rain fall and sun shine hours recorded at ZAHRS, Shivamogga and

Table 1. Insect pests recorded on cashew at ZAHRS, Shivamogga during 2021-22

Common Name	Scientific Name	Plant parts affected	Order: Family
Leaf miner	*Acrocercops syngramma* (Meyrick)	Leaf	Lepidoptera: Gracillariidae
Leaf roller	*Caloptilia iselaea* (Meyrick)	Leaf	Lepidoptera: Tortricidae
Leaf and blossom webber	*Lamida moncusalis* Walker	Leaf and panicle	Lepidoptera: Pyralidae
Apple and nut borer	*Thylacoptila paurosema* (Meyrick)	Immature fruits and nuts	Lepidoptera: Pyralidae
Hairy caterpillar	*Euproctis subnotata* Walker	Leaf and panicle	Lepidoptera: Lymantridae
Tea mosquito bug	*Helopeltis antonii* Signoret	Leaf, panicle and nuts	Hemiptera: Miridae
Tea mosquito bug	*Helopeltis bradyi* Waterhouse	Leaf, panicle and nuts	Hemiptera: Miridae
Mealy bug	*Planococcus citri* Risso	Leaf, panicle and nuts	Hemiptera: Pseudococcidae
Aphids	*Aphis odinae* (van der Goot)	Panicle and nuts	Hemiptera: Aphididae
Scale insect	*Coccus hesperidum* L.	Leaf and nuts	Hemiptera: Coccidae
Brown marmorated stink bug	*Halyomorpha halya* (Stal)	Leaf and Shoot	Hemiptera: Pentatomidae
Gundhi bug	*Leptocorisa acuta* (Thunberg)	Shoot	Hemiptera: Alydidae
Planthopper	*Amrasca biguttala biguttala* (Ishida)	Leaf and shoot	Hemiptera: Cicadellidae
Red banded thrips	*Selenothrips* sp.	Leaf	Thysanoptera: Thripidae
Thrips	*Scirtothrips dorsalis* Hood	Panicle and nuts	Thysanoptera: Thripidae
Long horned grass hopper	*Conocephalus* sp.	Leaf and shoot	Orthoptera: Tettigonidae
Cashew stem and root borer	*Plocederus ferrugenius* L.	Stem and root	Coleoptera: Cerembycidae
Fruit beetle	*Carpophilus* sp.	Apples	Coleoptera: Nitidulidae
Tortoise beetle	*Aspidomorpha* sp.	Leaf	Coleoptera: Chrysomelidae
Weevil	*Myllocerus* sp.	Leaf and trunk	Coleoptera: Curculionidae
Fruit fly	*Drosophila* sp.	Apples	Diptera: Drosophilidae
Termite	*Odontotermus* sp.	Stem and roots	Isoptera: Termitidae

AHRS, Bavikere during 2021-22 and represented in table 4. Correlation studies with weather parameters revealed that maximum temperature (r = -0.178) and rainfall (r = -0.041) had non-significant negative correlation and all the other weather parameters *viz*., minimum temperature (r = 0.321), morning relative humidity (r = 0.282), evening relative humidity (r = 0.314) and sun shine hours (r = 0.022) had non-significant positive correlation with the occurrence of leaf miner. These results are in line with Rao *et al*. (2006) who reported negative and non-significant correlation between the leaf miner incidence and maximum temperature (-0.427) and positive and non-significant correlation with morning relative humidity (0.248). The incidence of tea mosquito bug had significant positive correlation with minimum temperature (r = 0.600*). These results are in line with Vidya *et al.* (2015) who revealed that sunshine hours had a positive relation (0.516) with the activity of TMB. The occurrence of thrips had highly significant negative correlation with evening relative humidity (r = -0.757**) and significant positive correlation with sun shine hours (r = 0.506). These results are in agreement with

a. Infested young leaves

b. Young larvae scraping the leaves

c. Adult of *Acrocercops syngramma*

d. Matured larva before pupation

e. Infested leaves in nursery

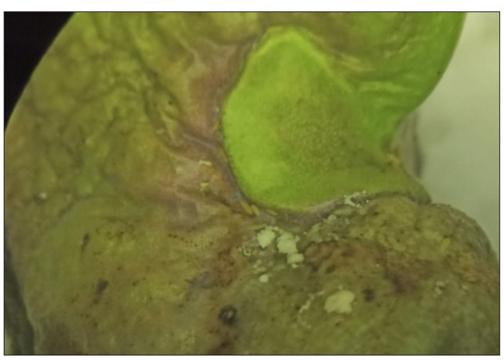
Plate 1. Leaf miner, *Acrocercops syngramma* damage in the field and nursery

a. *Helopeltis antonii*

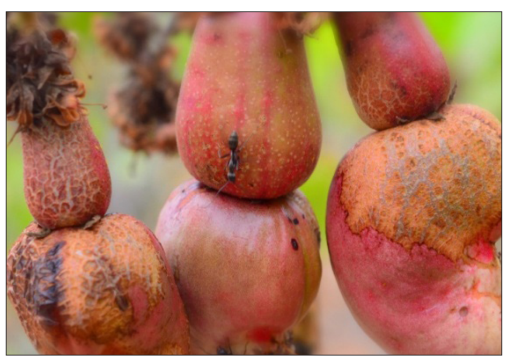
b. *Helopeltis bradyi*

c. Infestation of adult tea mosquito bugs on shoots

Plate 2. Damaging symptoms of tea mosquito bug, *Helopeltis* spp. on shoots, leaf stalks, immature fruits and nuts



a. Infestation of thrips, *Scirtothrips dorsalis* on nut surface



b. Crinkling symptoms

Plate 3. *Thrips, Scirtothrips dorsalis* damaging symptoms on nut surface

Table 2. Seasonal and per cent incidence of leaf miner (LM), tea mosquito bug (TMB) and thrips on cashew at ZAHRS, Shivamogga during 2021-22

SMW	Time		Mean No. of LM larvae/20 leaves	Per cent incidence of LM/20 leaves	Mean No. of TMB/20 shoots	Per cent incidence of TMB/20 shoots	Mean No. of Thrips/ 20 panicles	Per cent incidence of thrips/20 nuts
	Month	Week						
35	September (2021)	I	0.00	0.00	0.00	0.00	0.00	0.00
36		II	0.00	0.00	0.00	0.00	0.00	0.00
37		III	0.00	0.00	0.00	0.00	0.00	0.00
38		IV	0.00	0.00	0.00	0.00	0.00	0.00
39	October	I	0.00	0.00	0.00	0.00	0.00	0.00
40		II	0.00	0.00	0.00	0.00	0.00	0.00
41		III	0.00	0.00	0.00	0.00	0.00	0.00
42		IV	1.06	5.30	0.00	0.00	0.00	0.00
43		V	1.96	9.80	1.04	5.25	0.00	0.00
44	November	I	2.30	11.50	1.75	8.75	0.00	0.00
45		II	2.42	12.10	2.85	14.25	0.00	0.00
46		III	3.71	18.55	4.55	22.75	0.00	0.00
47		IV	4.54	22.70	4.80	24.25	0.00	0.00
48	December	I	4.33	21.65	5.49	27.25	0.00	0.00
49		II	3.47	17.35	6.50	32.75	0.00	0.00
50		III	2.69	13.45	6.05	31.75	0.07	0.00
51		IV	2.49	12.45	5.50	27.50	0.10	0.00
52		V	2.21	11.05	4.70	23.50	0.35	0.00
1	January (2022)	I	1.88	9.40	4.50	22.50	0.85	0.00
2		II	1.69	8.45	3.55	17.75	1.50	0.00
3		III	1.29	6.45	2.90	14.50	3.40	0.00
4		IV	1.07	5.35	1.95	9.75	4.08	0.00
5	February	I	0.79	3.95	1.70	8.50	5.65	0.00
6		II	0.60	3.00	0.90	4.50	6.30	1.75
7		III	0.26	1.30	0.00	0.00	6.70	2.25
8		IV	0.00	0.00	0.00	0.00	5.90	4.25
9	March	I	0.00	0.00	0.00	0.00	4.55	7.50
10		II	0.00	0.00	0.00	0.00	3.35	17.25
11		III	0.00	0.00	0.00	0.00	2.25	24.00
12		IV	0.00	0.00	0.00	0.00	1.30	28.25
13		V	0.00	0.00	0.00	0.00	0.45	33.00
14	April	I	0.00	0.00	0.00	0.00	0.00	33.75
15		II	0.00	0.00	0.00	0.00	0.00	29.27
16		III	0.00	0.00	0.00	0.00	0.00	23.00
17		IV	0.00	0.00	0.00	0.00	0.00	16.75
18	May	I	0.00	0.00	0.00	0.00	0.00	11.25
19		II	0.00	0.00	0.00	0.00	0.00	6.50
20		III	0.00	0.00	0.00	0.00	0.00	2.25
21		IV	0.00	0.00	0.00	0.00	0.00	0.00

***SMW- Standard Meteorological Week**

Table 3. Seasonal and per cent incidence of leaf miner in cashew nursery at AHRS, Bavikere during 2021

SMW	Time		Mean No. of larvae/25 leaves	Per cent incidence
	Month	Week		
30	July (2021)	IV	1.68	6.72
31	August	I	1.96	7.84
32		II	2.06	8.22
33		III	1.73	6.92
34		IV	1.27	5.08
35	September	I	1.82	7.26
36		II	2.38	9.50
37		III	2.63	10.52
38		IV	2.02	8.06
39	October	I	0.91	3.64
40		II	1.18	4.70
41		III	1.46	5.84
42		IV	1.88	7.52
43		V	2.08	8.30
44	November	I	2.36	9.44
45		II	3.07	12.26
46		III	4.13	16.50
47		IV	3.52	14.06
48	December	I	4.02	16.08
49		II	2.98	11.92
50		III	2.56	10.22
51		IV	2.27	9.08
52		V	1.06	4.24

***SMW- Standard Meteorological Week**

Table 4. Correlation of major insect pests of cashew with weather parameters during 2021-22

Insect pests	Correlation coefficient (r) (ZAHRS, Shivamogga)					
	Temperature (°C)		Relative humidity (%)		Rainfall (mm) (X_5)	Sun shine hours (X_6)
	Max T° (X_1)	Min T° (X_2)	RH I (X_3)	RH II (X_4)		
Acrocercops syngramma	-0.178	0.321	0.282	0.314	-0.041	0.022
Helopeltis spp.	-0.427	0.600*	0.456	0.444	-0.109	0.029
Scirtothrips dorsalis	0.350	-0.135	-0.385	-0.757**	-0.250	0.506*
Insect pest	**Correlation coefficient (r) (AHRS, Bavikere)**					
	Temperature (°C)		Relative humidity (%)		Rainfall (mm) (X_5)	Sun shine hours (X_6)
	Max T° (X_1)	Min T° (X_2)	RH I (X_3)	RH II (X_4)		
Acrocercops syngramma	-0.111	-0.239	-0.461*	-0.625**	-0.293	0.063

****Significant at 1% level; *Significant at 5% level; R^2 = Coefficient of determination**

X_1 = Maximum temperature, X_2 = Minimum temperature, X_3 = Morning relative humidity, X_4 = Evening relative humidity, X_5 = Sun shine hours and X_6 = Rainfall

a. *Ischiodon scutellaris*

b. *Coccinella transversalis*

c. *Oecophylla* sp.

d. Mantidfly

e. *Chrysoperla* sp.

Plate 4. Natural enemies in cashew ecosystem

Table 5. Natural enemies recorded on insect pests of cashew during 2021-22

Common Name/ Scientific Name	Family: Order	Host	Collected from (Stage)
Mantidflies (Unidentified)	Mantispidae: Neuroptera	Tea mosquito bug, *Helopeltis* spp.	Nymphs and adults
Lady bird beetle (*Coccinella transversalis*)	Coccinellidae: Coleoptera	Aphids, *Aphis odinae*	Nymphs and adults
Green lace wing (*Chrysoperla* sp.)	Chrysopidae: Neuroptera	Tea mosquito bug, *Helopeltis* spp. and thrips, *Scirtothrips dorsalis*	Nymphs and adults
Red ants (*Oecophylla* sp.)	Formicidae: Hymenoptera	Tea mosquito bug, *Helopeltis* spp., Mealy bugs, *Planococcus citri* and aphids, *Aphis odinae*	Nymphs and adults
Hover flies (*Ischiodon scutellaris*)	Syrphidae: Diptera	Aphids, *Aphis odinae*	Nymphs and adults

Jalgaokar *et al*. (2015) who revealed that the maximum temperature (0.423) and sunshine hours had positive correlation (0.482), whereas, the minimum temperature (-0.263) and the rainfall (-0.382) had non-significant negative correlation with the red banded thrips incidence. The leaf miner incidence had highly significant negative correlation with evening relative humidity (r = -0.625**) and significant negative correlation with morning relative humidity (r= -0.461*) in cashew nursery. These results are in line with Rao *et al*. (2006) who reported negative and non-significance correlation between the leaf miner incidence and maximum temperature (-0.427). The natural enemies recorded on insect pests of cashew included, different predators *viz*., mantidflies, *Coccinella transversalis, Chrysoperla* sp., red ants, *Oecophylla* sp. and hover flies, *Ischiodon scutellaris* (Plate 4) (Table 5). These results are in line with Sundararaju (1984) who reported that neuropteran predator, *Chrysoperla* was found to feed on tea mosquito bugs in the field. Sundararaju (1993a) also reported that *Helopeltis antonii* was preyed upon by five species of a spiders and a cocinellid. These results are also in line with Naik and

Chakravarthy (2013) who reported the ant, *Oecophylla smaragdina* F. was the most effective predator on TMB.

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MS Received: 02 February 2025
MS Acceptance:24 April 2025

Pest Management in Horticultural Ecosystems
Vol. 31, No.1 pp 24-34 (2025)
DOI Number : 10.5958/0974-4541.2025.00007.6

Comparative diversity of pests and their natural enemies in organic and conventional farming systems of tomato

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ABSTRACT: Comparative biodiversity of insects and mites was studied in organic and conventional farming systems (FS) of tomato at certified organic farming unit of ASPEE College of Horticulture and Forestry (ACHF) and conventional farm of N. M. College of Agriculture (NMCA), Navsari Agricultural University, Navsari, Gujarat during 2018 – 2020, respectively. Total 1016 insect and mite individuals belonging to 9 insect and 1 mite orders, 14 insect and 2 mite families of 20 species of insects and 2 mites were recorded at organic farm (FS) against 967 individuals belonging to 8 insect and 1 mite orders, 13 insect and 2 mite families containing 17 insect and 2 mite species at conventional farm (FS). The diversity of insect and mites was higher in organic as compared to conventional FS. Higher species richness (22), species abundance (1016), species evenness (J= 0.76), species richness index (R= 3.03) and Shannon diversity index (H= 2.36) was observed at organic FS against lower species richness (19), species abundance (967), species evenness (0.69), species richness index (2.62) and Shannon diversity index (2.04) in conventional FS. Insect order Hemiptera and mite order Acarina were more represented at conventional farm (49.63 and 30.50 %) as compared to organic farm (46.99 and 24.17 %). Insects of Coleoptera order were more abundant at organic FS as compared to conventional FS. Relative abundance of herbivores was higher (82.10 %) with lower species evenness (0.71), species richness (1.20) and Shannon diversity index (1.55) in conventional FS as compared to lower relative abundance (69.68 %) with higher species evenness (0.74), species richness (1.37) and Shannon diversity index (1.71) in organic tomato FS. Similarly, 288 insect and mite predators were recorded at organic farm as compared to 161 individuals of insect and mite predators in conventional tomato FS. The relative abundance of predators was higher (28.30 %) with higher species evenness (0.70), species richness (1.59) and Shannon diversity index (1.64) at organic farm whereas, relative abundance (16.55 %), species evenness (0.67), species richness (1.59) and Shannon diversity index (1.64) remained lower at conventional farm. Similarly, higher parasitoids (21), relative abundance (2.02 %), species evenness (0.96), species richness (0.37) and Shannon weiner index (0.67) was observed in organic FS as compared to conventional FS (15, 1.52, 0.91, 0.34 and 0.63). In the present investigation, no pollinators were observed in both the farming systems.

Keywords: Biodiversity, conventional farming system, herbivores, insect, mite, tomato organic farming system, parasitoids, predators.

INTRODUCTION

There are about 1.7 million species of plants and animals living on the earth. Of these, about 0.25 million are plants and the rest being animals and amongst these, nearly one million are insects. However, there are many that remain unidentified (Anonynous, 1992).

The Arthropoda, which includes insects, spiders, mites, and their relatives, is the most successful and diverse group of organisms on the planet. Insects alone account for nearly 55 per cent of all the species (Barrowclough, 1992). Agricultural ecosystems that are rich in biodiversity possess greater resilience and are, therefore, able to recover more readily from biotic and abiotic stresses such as drought, environmental degradation, pests, diseases, epidemics, among others (Wilsey & Polley, 2002; Wittebolle *et al*., 2009). The so-called “conventional” agricultural model was largely adopted after the green revolution. Its intensification and expansion represent a threat to global biodiversity because it causes homogenization of agricultural landscapes, habitat loss and reduction, and increased use of pesticides and synthetic chemical fertilizers (Bengtsson *et al.,* 2005). Thus, there is an increasing search for alternative crop systems based on ecological principles that would allow agriculture to benefit from biodiversity. Within this tendency, organic agriculture, which began around 1970s, became an alternative based in safer and sustainable principles for the environment and human societies (Anonymous, 2009).

Many studies in the recent past have suggested that organic farming enhances the biodiversity in agricultural landscapes as compared to conventional farming. Though organic system enhances species richness and abundance, its effects are likely to differ between organism groups and landscapes (Hole *et al.*, 2005; Bengtsson *et al.,* 2005). It has been established that "organic farming" can lead to higher populations and species diversity of predators, parasitoids as compared to conventional farming (Booij & Noorlander 1992; Gnanakumar *et al.,* 2012). A meta-analysis of biodiversity on organic versus conventional farms indicate 30 per cent higher species richness on organic farms. Positive effects of organic farming in the meta-analysis were measured for plants, arthropods, carabid beetles, predatory insects and birds (Bengtsson, *et al.,* 2005). A review of 76 studies on organic and conventional farms showed a positive effect of organic agriculture on species abundance and/or richness in 66 cases; 25 had neutral or mixed outcomes, and only eight showed a negative effect on biodiversity (Hole *et al.,* 2005) whereas, a majority of the studies showed an increase in abundance, richness or both, on organic compared to conventional farms.

Gujarat is the sixth largest state in India having 9.89 million hectares agricultural land contributing to 6.23 per cent of the total Indian agricultural land, of which 47775.62 ha. is organic. The major vegetable crops grown in south Gujarat are okra, tomato, brinjal, Indian bean. Amongst them, tomato (*Lycopersicon esculentum* Mill.) is grown in almost every district of south Gujarat (Anonymous, 2014). Butani and Verma (1976) listed as many as 16 species of insect and non-insect pests infesting tomato crop from germination to harvesting stage. Amongst them, tomato fruit borer, *Helicoverpa armigera* (Hub.), jassid, *Amrasca biguttula biguttula* (Ishida) and *Empoasca punjabensis* (Pruthi), tobacco caterpillar, *Spodoptera litura* (Fab.), thrips, *Thrips tabaci* (Linn.), aphids, *Aphis gossypii* (Glover), *Lipaphis erysimi* (Kalt.) and *Myzus persicae* (Sulzer), whitefly, *Bemisia tabaci* (Genn.) and epilachna beetle, *Epilachna dodecastigma* (Wiedemann), etc. occur regularly. Fruit borer, *H. armigera* is the most destructive insect pest causing considerable losses in quantity as well as quality of tomato fruits (Tiwari and Krishnamoorthy, 1984; Reddy and Zehr, 2004). Srinivas and Sushil Kumar (2025) recorded incidence of fruit borer, whitefly and red spider mite in both the farming systems (organic and conventional) of tomato cv. GT-2. The incidence of these pests was higher in the late stages of the crop.

Aleksandar Ivezic *et al*. (2025) revealed that conventional reliance on chemical pesticides as the primary pest control method has led to various adverse outcomes, impacting pest management effectiveness and reducing product quality. Information on diversity of insects and mites in a particular farming system is a pre-requisite, which helps in designing a successful pest management strategy. However, no systematic efforts have been made to study the diversity of insects and mites in both conventional and organic farming systems of tomato in south Gujarat.

Therefore, the study on comparative biodiversity of insects and mites in organic and conventional farming systems of tomato was undertaken at Navsari Agricultural University, Navsari, Gujarat during 2018-2020.

MATERIALS AND METHODS

Studies on comparative biodiversity of insects and mites in organic and conventional farming systems of tomato were carried out under field conditions at certified organic farming unit of ASPEE College of Horticulture and Forestry and conventional farm, N. M. College of Agriculture, Navsari Agricultural University, Navsari, Gujarat, India during 2018-2020 with tomato cv. GT-2.

Sampling Procedure

Insects and mite pests on tomato were collected at fortnightly interval on 25 randomly selected plants (5 plants/spot in "W" shape) of middle rows, leaving the border row plants in both the farming systems by visual observation and plant inspection method as suggested by Southwood, 1978. The above ground insect species were trapped in sweep nets (32 cm dia. and 70 cm long) and were monitored. Five sweeps were done and fortnightly data (average of two standard weeks) (Table 1) on the number of individuals of each species obtained by net sweeping was used to formulate the biodiversity of insects.

Observations on pollinators were made using Ad-libitum sampling of flower visitors for a sampling time of ten minutes with a time interval of 60 min. However, no pollinator was identified in both the farming systems of tomato in this investigation. The population of sucking pests were visually recorded on 3 leaves (top, middle and bottom leaves).

The insects collected by various methods were brought to the laboratory and killed by placing a small cotton swab dipped in ethyl acetate inside the polythene bags. The identification of the collected specimens from both the farming systems was confirmed taxonomically. The data were used to calculate species abundance, species richness, evenness; Shannon-Weaver diversity index (often called Shannon-Weiner index) for each taxonomic order in both organic and conventional fields and then biodiversity was compared between the two farming-based ecosystems.

Statistical Analysis

PAST software was used to calculate the diversity indices.

Species Diversity: Shannon and Wiener diversity index (H') is the most popular and widely used index in community ecology. It is the average degree of 'uncertainty' and if this average 'uncertainty' increases as the number of species increase, distribution of individuals among the species also become even. Insect and mite diversity in both the farming systems were assessed using Shannon-Weaver diversity formula and is as under:

$\mathbf{H = \Sigma\, p_i \log_2 p_i}$ …………… (Shannon – Weiner, 1963)

Where, H = Diversity index

$P_i = n_i / N$

P_i= Proportion of individuals of i^{th} species.

n_i = Number of individuals of each species in the sample.

N = Total number of individuals of all species in the sample.

Species Evenness: How equally abundant the species are. There are many measures of evenness proposed. One of the most common approaches has been to scale one of the heterogeneity measures such as the Shannon-Weaver diversity measure, relative to its maximum theoretical value when each species in the sample was represented by the same number of individuals.

$$J = \frac{H}{\log \lambda S}$$ .... (Pielou, 1969)

Where, 'H' is the Shannon-Weaver diversity and 'S' is the number of species in the community.

Species Richness: In order to assess how the diversity of the population is distributed or organised among the particular species, this index was calculated.

$$R = \frac{S-1}{\log \lambda N}$$ .... (Margalef, 1958)

Where, 'S' is the total number of species collected and 'N' is the total number of individuals in all the species.

Relative Abundance: The relative abundance of different species was calculated in terms of percentage.

% Relative abundance (RA) =n/N*100

Where, n = Total number of individuals of species 'a'

N = Total number of individuals of all species.

Pest wise observational methodology in organic and conventional farming systems

Tomato

Twenty-five randomly selected plants in 5 spots. Five plants/spot in "W" shape in both organic and conventional farming systems.

Fruit borer, *H. armigera* and Fruit damage

During vegetative stage of the crop, number of fruit borer larvae was counted on 25 randomly selected plants in each farming systems. During fruiting stage, *H. armigera* was considered as a fruit borer. Therefore, at every picking, damaged and healthy marketable fruits were sampled from 25 selected plants of each farming systems and their numbers were counted. Percent fruit infestation was worked out using the formula (Rahman *et al.,* 2009).

$$\text{Percent Fruit infestation} = \frac{\text{Number of damaged Fruits}}{\text{Total no. of healthy fruits}} \times 100$$

Sucking pests

Observations on whitefly, *B. tabaci* population were counted from three (top, middle and bottom) leaves whereas; Red spider mite, *T. urticae* population was recorded from the same leaves of 2 cm^2 area on randomly selected 25 plants from each farming systems. The counts were continued from transplanting to harvest of the crop.

RESULTS AND DISCUSSION

The present investigation based on **"Comparative biodiversity of insects and mites in organic and conventional farming systems of tomato"** was undertaken in two different farming systems of tomato

Table 1. Details of standard week and crop stages of tomato during the study period at organic and conventional systems during 2018 - 20

Sr. No.	SMW	Standard Period	Crop Stage (Tomato)
1	50	10 Dec - 16 Dec	Vegetative Stage
2	51	17 Dec - 23 Dec	Vegetative Stage
3	52	24 Dec - 31 Dec	Vegetative Stage
4	1	01 Jan - 07 Jan	Vegetative Stage
5	2	08 Jan - 14 Jan	Flowering Stage
6	3	15 Jan - 21 Jan	Flowering Stage
7	4	22 Jan - 28 Jan	Flowering Stage
8	5	29 Jan - 04 Feb	Fruiting Stage
9	6	05 Feb - 11 Feb	Fruiting Stage
10	7	12 Feb - 18 Feb	Fruiting Stage
11	8	19 Feb - 25 Feb	Fruiting Stage
12	9	26 Feb - 04 Mar	Fruiting Stage
13	10	05 Mar - 11 Mar	Fruiting Stage

SMW- Standard Meteorological Week

i.e. Certified Organic Farming Unit, ASPEE College of Horticulture and Forestry (organic FS) and Conventional farm, N. M. College of Agriculture, Navsari Agricultural University, Navsari (conventional FS) for a period of two years from 2018 to 2020. Year wise observations were recorded in both the farming systems of tomato cv. GT-2. The major aspects such as species richness, abundance, relative abundance and diversity indices have been studied in the designated crop and compared for both the farming systems and the results obtained are presented hereunder:

Insect and mite diversity at organic and conventional farming systems of tomato during 2018-20

In the present investigation, total number of 1016 insect and mite individuals belonging to 9 insect and 1 mite orders, 14 insect and 2 mite families comprising of 20 insect and 2 mite species were recorded in organic farming system (FS) of tomato while, 967 individuals belonging to 8 insect and 1 mite orders, 13 insect and 2 mite families representing 17 insect and 2 mite species were observed in conventional FS. The diversity of insect and mites was higher in organic FS as compared to conventional FS. Higher species richness (S=22), species abundance (N=1016), species evenness (J= 0.76), species richness index (R= 3.03) and shannon diversity index (H= 2.36) were observed at organic FS in comparison to lower species richness (19), species abundance (967), species evenness (0.69), species richness index (2.62) and shannon diversity index (2.04) at conventional tomato FS (Table 2).

Similar observations were made by Bengtsson *et al.* (2005), Hole *et al*. (2005), Barros *et al.* (2018) who collected a total of 56,955 insects from 25 families from the organic tomato system and 10,660 from 22 families in the conventional tomato FS. They further recorded significantly higher insect diversity and relative abundance (AR) in organic tomato FS as compared to conventional FS. The average diversity indices were as follows: For the organic system: Shannon- Wiener, 2.97; Simpson, 0.79; Simpson Dominance, 0.19; Margalef, 5.13; and Pielou, 2.27, respectively. For the conventional system, the indices were 3.49; 0.86; 0.12; 6.93; and 2.56; respectively. Youngberg *et al*. (1984) have compared the biodiversity of natural enemies and phytophagous insects between organic and chemical farming systems in the Sacramento Valley. They found higher richness (61 species) in organic samples as compared to chemical field samples (35 species) which supports the current investigation.

Table 2. Insect and mite diversity in organic and conventional farming systems of tomato

Sr. No.	Order	Family	Scientific name	2018-19		2019-20		Pooled (2018-20)	
				Organic	Conventional	Organic	Conventional	Organic	Conventional
1	Hemiptera	Pentatomidae	*Nezara viridula*	10	7	8	5	9	6
			Eucanthecona furcellata	7	0	3	0	5	0
			Geocoris tricolor	8	6	4	3	6	5
		Miridae	*Dicyphus hesperus*	147	102	139	87	143	95
		Aleyurodidae	*Bemisia tabaci*	129	161	134	153	132	157
		Aphididae	*Myzus persicae*	176	227	183	203	180	215
2	Lepidoptera	Noctuidae	*Helicoverpa armigera*	39	20	33	17	36	19
			Spodoptera litura	16	10	16	10	16	10
			Otheris materna	4	3	7	3	6	3
3	Coleoptera	Coccinellidae	*Harmonia octomaculata*	12	0	4	0	8	0
			Cheilomenes sexmaculata	42	13	46	17	44	15
			Coccinella transversalis	34	15	26	19	30	17
4	Diptera	Agromyzidae	*Liriomyza trifoli*	25	18	16	11	21	15
		Syrphidae	*Ischidon scutellaris*	10	6	7	4	9	5
		Tachinidae	*Carcelia* sp.	15	9	12	9	14	9
5	Hymenoptera	Braconidae	*Apanteles* sp.	8	5	6	6	7	6
6	Orthoptera	Acrididae	*Cyrtacanthacris tatarica*	3	0	1	0	2	0
7	Mantodea	Mantidae	*Mantis religiosa*	5	3	2	2	4	3
8	Neuroptera	Chrysopidae	*Chrysoperla zastrowii*	33	14	25	11	29	13
9	Thysanoptera	Thripidae	*Thrips tabaci*	69	76	68	83	69	80
10	Acarina	Tetranychidae	*Tertanychus urticae*	260	308	211	263	236	286
		Phytoseiidae	*Amblyseius orientalis*	10	8	9	8	10	8
			No. of species (S)	22	19	22	19	22	19
			No. of Families	16	15	16	15	16	15
			No. of Orders	10	9	10	9	10	9
			N	1062*	1011*	960*	914*	1016*	967*
			J	0.77	0.69	0.75	0.69	0.76	0.69
			R	3.01	2.60	3.06	2.64	3.03	2.62
			H	2.38	2.03	2.31	2.04	2.36	2.04

S- No. of species, N- Total no. of individuals in all species, J- Species evenness, R- Species Richness, H- Shannon-Wiener index *Number of insects per 300 plants and 12 sampling dates, mites recorded on 2cm^2 leaf area

Rundlof and Smith (2006) studied the effect of farming practice on insect species richness and abundance on organic and chemical farms in homogeneous and heterogeneous landscape diversity. They found that organic farming and landscape heterogeneity significantly increased insect species richness and abundance. Maria *et al.* (2014) revealed that species richness and abundance were significantly higher in organic crops and insects were thirty-four per cent more abundant on organic crops compared to conventionally grown crops. Comparing studies at different landscape scales (plot, farm, and landscape matrix), organic crops had a positive effect, with greatest effect at the plot level which supports the present findings.

During the study period, the relative abundance of individual phytophagous insect and mite species (herbivores) were found higher in both organic and conventional tomato farming systems. However, relative abundance of natural enemies (predators and parasitoids) was higher in organic tomato farming system as compared to conventional farming system. The present findings are more or less similar with Drinkwater *et al.* (1995) reported that abundance of arthropod herbivores was similar in organic and conventional tomato farms whereas patterns of species richness and abundance of predators and parasitoids were significantly different in organic and conventional farms. Species richness of predators and parasitoids was more than 75 per cent greater, and natural enemies were 80 per cent more abundant, on organic tomato farms than on conventional farms.

The relative abundance of aphid, *M. persicae* (17.82 and 22.37 %), phytophagous mite, *T. urticae* (23.23 and 29.67 %), whitefly, *B. tabaci* (13.05 and 16.36 %) and thrips, *T. tabaci* (6.79 and 8.31 %) was higher in organic than conventional tomato FS. Likewise, relative abundance of natural enemies like ladybird beetle *C. sexmaculata* (4.37 and 1.58 %), *C. transversalis* (2.95 and 1.78 %) and mirid bug, *D. hesperus* (14.16 and 9.82 %) were higher at organic farms as compared to conventional tomato FS (Table 3).

This finding is very well in line with the result of a similar study conducted by Yardim and Edwards (2003) who also reported that predatory anthocorids were higher on tomato plants with high aphid populations in the organic than in the conventional plots. They concluded that increased natural enemy population might be due to presence of nontoxic environment and in turn resulted in faster multiplication rate.

In the present investigation, insects of order Hemiptera were relatively more abundant followed by mite order Acarina and insect order Thysanoptera at conventional farm (49.63, 30.50 and 8.31 %) as compared to organic farm (46.99, 24.17 and 6.79 %). However, insects of order Coleoptera (8.10 and 3.36 %) and Lepidoptera (5.69 and 3.28 %), were relatively more abundant at organic farm as compared to conventional farm, respectively followed by Diptera, Neuroptera, Hymenoptera and Mantodea. On the other hand, insects of order Orthoptera were not recorded at conventional tomato farm which might be due to absence of weed flora around the field and ill effects of pesticide spray (Table 4).

Table 3. Relative abundance (%) of insects and mites in organic and conventional farming systems of tomato

Sr. No.	Order	Family	Scientific name	2018-19		2019-20		Pooled (2018-20)	
				Organic	Conventional	Organic	Conventional	Organic	Conventional
1	Hemiptera	Pentatomidae	*Nezara viridula*	0.94	0.69	0.83	0.55	0.89	0.62
			Eucanthecona furcellata	0.66	0.00	0.31	0.00	0.49	0.00
			Geocoris tricolor	0.75	0.59	0.42	0.33	0.58	0.46
		Miridae	*Dicyphus hesperus*	13.84	10.09	14.48	9.55	14.16	9.82
		Aleyurodidae	*Bemisia tabaci*	12.15	15.92	13.96	16.79	13.05	16.36
		Aphididae	*Myzus persicae*	16.57	22.45	19.06	22.28	17.82	22.37
2	Lepidoptera	Noctuidae	*Helicoverpa armigera*	3.67	1.98	3.44	1.87	3.55	1.92
			Spodoptera litura	1.51	0.99	1.67	1.10	1.59	1.04
			Otheris materna	0.38	0.30	0.73	0.33	0.55	0.31
3	Coleoptera	Coccinellidae	*Harmonia octomaculata*	1.13	0.00	0.42	0.00	0.77	0.00
			Cheilomenes sexmaculata	3.95	1.29	4.79	1.87	4.37	1.58
			Coccinella transversalis	3.20	1.48	2.71	2.09	2.95	1.78
4	Diptera	Agromyzidae	*Liriomyza trifoli*	2.35	1.78	1.67	1.21	2.01	1.49
		Syrphidae	*Ischidon scutellaris*	0.94	0.59	0.73	0.44	0.84	0.52
		Tachinidae	*Carcelia* sp.	1.41	0.89	1.25	0.99	1.33	0.94
5	Hymenoptera	Braconidae	*Apanteles* sp.	0.75	0.49	0.63	0.66	0.69	0.58
6	Orthoptera	Acrididae	*Cyrtacanthacris tatarica*	0.28	0.00	0.10	0.00	0.19	0.00
7	Mantodea	Mantidae	*Mantis religiosa*	0.47	0.30	0.21	0.22	0.34	0.26
8	Neuroptera	Chrysopidae	*Chrysoperla zastrowii*	3.11	1.38	2.60	1.21	2.86	1.30
9	Thysanoptera	Thripidae	*Thrips tabaci*	6.50	7.52	7.08	9.11	6.79	8.31
10	Acarina	Tetranychidae	*Tertanychus urticae*	24.48	30.46	21.98	28.87	23.23	29.67
		Phytoseiidae	*Amblyseius orientalis*	0.94	0.79	0.94	0.88	0.94	0.83
		Total		**100**	**100**	**100**	**100**	**100**	**100**

Table 4. Relative abundance (%) of insect and mite orders in organic and conventional tomato farming systems

Order	2018-19		2019-20		Pooled (2018-20)	
	ORG	CONV	ORG	CONV	ORG	CONV
Hemiptera	44.92	49.75	49.06	48.06	46.99	49.63
Orthoptera	0.28	0	0.10	0	0.19	0
Mantodea	0.47	0.30	0.21	0.22	0.34	0.26
Coleoptera	8.29	2.27	7.92	3.95	8.10	3.36
Hymenoptera	0.75	0.49	0.63	0.66	0.69	0.58
Thysanoptera	6.50	7.52	7.08	9.11	6.79	8.31
Lepidoptera	5.56	3.26	5.83	3.29	5.69	3.28
Diptera	4.71	3.26	3.65	2.63	4.18	2.95
Neuroptera	3.11	1.38	2.60	1.21	2.86	1.30
Acarina	25.42	31.26	22.92	29.75	24.17	30.50

In the present investigation, species abundance and relative abundance of herbivores was higher in conventional FS (791 and 82.10%) as compared to organic farming system FS (707 and 69.68 %) (Table 5). However, species abundance and relative abundance of predators and parasitoids was higher in organic farm (N= 288 and 21) (RA= 28.30 and 2.02 %) as compared to conventional tomato FS (N= 161 and 15) (RA = 16.55 and 1.52%) (Table 6,7). The results of Culliney and Pimentel (1986) and Dialoke *et al.* (2013) where phytophagous insect populations were lower in organic farms than chemical fertilizer applied field supports the present findings.

Letourneau and Goldstein (2001) reported that arthropod damage to leaves and fruit was similar in commercial tomatoes produced under organic and conventional management. However, higher abundance of natural enemies and greater species richness of all functional arthropod groups was observed in organic systems than conventional farming system. Scarlato *et al*. (2023) indicated that organic farms had yields comparable to conventional farms, a lower abundance of pests, less pest injury, and a higher abundance of natural enemies. The cumulative pest: natural enemies ratio was 9 for organic and 38 for conventional management. In the present study, the abundance (N=791) and relative abundance (82.10 %) of herbivores was higher with lower species evenness (J= 0.71), species richness (R= 1.20) and Shannon diversity index (H= 1.55) at conventional farm while, it was lower abundance (707) and relative abundance of herbivores (69.68 %) with higher species evenness

Similarly, 288 insect and mite predators comprising of 9 insect predator species and 1 predatory mite species were recorded at organic farm as compared to 161 individuals comprising of 7 insect and 1 mite predator species at conventional farm. The relative abundance of predators was higher (28.30 %) with higher species evenness (J= 0.70), species richness (R= 1.59) and Shannon diversity index (1.64) at organic tomato farm while, lower relative abundance (16.55 %) with lower species evenness (J= 0.67), species richness (R= 1.38) and Shannon diversity index (H= 1.39) were assessed at conventional tomato farm (Table 6).

Crowder *et al.* (2010) reported higher activity of natural enemies in organic tomato farming systems which can be attributed to reduced use of broad-spectrum pesticides. Sean Clark (2001) also recorded greater predator abundance and species richness in organic tomato compared to conventional farming system. In the present investigation, species abundance and relative abundance of parasitoids were higher in organic as compared to conventional tomato FS. Higher species abundance (21), relative abundance (2.02 %), species evenness (0.96), species richness (0.37) and Shannon diversity index (0.67) were observed in organic tomato as compared to lower species abundance (15), relative abundance

Table 5. Species abundance, relative abundance and diversity indices for herbivores in organic and conventional tomato farming systems

Taxon	Herbivores					
	2018-19		2019-20		Pooled (2018-20)	
	ORG	CONV	ORG	CONV	ORG	CONV
S	10	9	10	9	10	9
N	731	830	677	748	707	791
RA (%)	68.83	82.10	70.52	82.11	69.68	82.10
J	0.74	0.70	0.74	0.71	0.74	0.71
R	1.37	1.19	1.38	1.21	1.37	1.20
H	1.71	1.55	1.70	1.55	1.71	1.55

ORG: Organic Farming System   CONV: Conventional Farming System

S- No. of species, N- Total no. of individuals in all species, RA- Relative abundance,
J- Species evenness, R- Species Richness, H- Shannon-Wiener index

(J= 0.74), species richness (1.37) and Shannon diversity index (H= 1.71) at organic tomato farm (Table 5).

(1.52 %), species evenness (0.91), species richness (0.34) and Shannon diversity index (0.63) of parasitoids at conventional tomato farming systems. The lower Shannon diversity values indicate very low parasitoid diversity in both organic and conventional tomato FS (7)(Table 7). This finding is very well in line with the results of a similar study conducted by Anbalagan *et al*. (2015), Gnanakumar *et al.* (2012) who also compared species diversity and richness of hymenopteran egg parasitoids between organic and conventional paddy ecosystems. They recorded higher Simpson's diversity index (H= 0.978) in organic ecosystem as compared to conventional paddy ecosystem (H= 0.878).

Berry *et al.* (2010) recorded significantly higher Hymenopteran parasitoids (9/0.1m^2 area), Staphylinidae (Coleoptera) (2/0.1m^2 area) and Hemerobiidae (Neuroptera) (1.5 /0.1m^2 area) in organic carrot crop as compared to conventional fields in New Zealand. Species richness, abundance and relative abundance of predators and parasitoids were higher in organic tomato systems as compared to conventional farm. Similar observations were reported by Reddy and Giraddi (2019) and Mazzei *et al.* (2021) who found greater insect diversity in organic and conservation crop blocks as compared to conventional system. Subhash Singh (2020) revealed that the organic farming system had an holistic approach in performing better than the conventional farming system with advantages like no chemicals, safety to human and animal health, species richness, abundance of insect predators and the pollinators.

Summarizing the entire study on insect and mite biodiversity in organic and conventional farming systems of tomato, it is evident that higher species richness, species abundance, species evenness and shannon diversity indices were recorded in organic farming systems as compared to conventional farming system. It has also been proved that organic farming practices can help in the population build-up of natural enemies like predators and parasitoids in tomato. The relative abundance of herbivores (phytophagous insects and mites) was lower in organic farming systems. So, it may be concluded that organic farming practices may encourage diversity of natural enemies and may not be favourable for pests. Additionally, the organic farming system methods promote the conservation of species of arthropods in all functional groups, which increases the abundance of natural enemies, compared to the conventional farming system. Bengtsson *et al.* (2005) in a meta-analysis on organic versus conventional farms reported a thirty per cent higher biodiversity on organic farms. Positive effects of organic farming in the meta-analysis were measured for plants, arthropods, carabid beetles, other predatory insects, and birds, but not for non-predatory arthropods or soil microorganisms.

Table 6. Species abundance, relative abundance and diversity indices for predators in organic and conventional tomato farming systems

Taxon	Predators					
	2018-19		2019-20		Pooled (2018-20)	
	ORG	CONV	ORG	CONV	ORG	CONV
S	10	8	10	8	10	8
N	308	167	265	151	288	161
RA (%)	29.00	16.52	27.60	16.58	28.30	16.55
J	0.74	0.66	0.66	0.67	0.70	0.67
R	1.57	1.37	1.61	1.40	1.59	1.38
H	1.70	1.38	1.52	1.40	1.64	1.39

Table 7. Species abundance, relative abundance and diversity indices for parasitoids in organic and conventional tomato farming systems

Taxon	Parasitoids					
	2018-19		2019-20		Pooled (2018-20)	
	ORG	CONV	ORG	CONV	ORG	CONV
S	2	2	2	2	2	2
N	23	14	18	15	21	15
RA (%)	2.17	1.38	1.88	1.65	2.02	1.52
J	0.93	0.89	0.98	0.92	0.96	0.91
R	0.36	0.32	0.37	0.35	0.37	0.34
H	0.65	0.62	0.68	0.64	0.67	0.63

ORG: Organic Farming System   CONV: Conventional Farming System

S- No. of species, N- Total no. of individuals in all species, RA- Relative abundance,
J- Species evenness, R- Species Richness, H- Shannon-Wiener index

ACKNOWLEDGMENTS

Authors are thankful to the establishment of Navsari Agricultural University, Gujarat for permission to carry out the research and providing adequate infrastructural facilities.

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MS Received: 22 April 2025
MS Acceptance: 30 May 2025

Pest Management in Horticultural Ecosystems
Vol. 31, No.1 pp 35-41 (2025)
DOI Number : 10.5958/0974-4541.2025.00006.X

Evaluation of combination insecticides for managing the insect pest complex in okra (*Abelmoschus esculentus*)

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ABSTRACT: A field investigation was undertaken to determine the efficacy of certain combination insecticides against insect pests of okra. Among the combination insecticides tested, the imidacloprid 40% + fipronil40%WG @ 500g/ha was observed to be the most effective against whitefly (*Bemisia tabaci*) with mean population of whitefly (2.24±0.06 per 3leaves; 1.61±0.12 per 3 leaves, 77.51% & 82.48% PROC, after first and second spray, respectively), jassid (*Amrasca biguttula biguttula*)with mean population of jassid (1.87±0.29 per 3 leaves; 1.21±0.22 per 3 leaves, 77.17% & 84.89% PROC after first and second spray, respectively) and shoot and fruit borer damage (*Earias vittella*) with lowest mean damage (3.40±0.13 per cent shoot damage and 2.61±0.07 per cent fruit damage, 71.36% & 78.87% PROC after first and second spray, respectively) and least effective treatments was profenofos 40% + Cypermethrin 4% EC 1250 ml/ha against whitefly and jassid, deltamethrin0.72%+ buprofezin5.65% EC500ml/ha against shoot and fruit borer. The maximum yield of 95.27 q/ha was found in imidacloprid 40% + fipronil 40% WG 500 g/ha, while the minimum yield of 85.83 q/ha was recorded in deltamethrin 1% + triazophos 35% EC 1000 ml/ha. Untreated plot recorded the yield 60.13 q/ha. The highest incremental cost-benefit ratio of 1:21.21 was recorded in thiamethoxam 12.6% + lambda cyhalothrin 9.5% ZC125ml/ha, while the lowest ratio was observed in imidacloprid 40%+ ethiprole40% WG 500 g/ha (1:3.33).

Keywords: Efficacy, whitefly, jassid, shoot & fruit borer, yield, incremental cost- benefit ratio.

INTRODUCTION

Okra, *Abelmoschus esculentus* (L.) Moench, is a vital vegetable crop widely cultivated in tropical and subtropical regions across the globe. The okra is attacked by roughly 72 different insect pest species from germination to harvest (Rao and Rajendran, 2002). The major causes of the high pest occurrence in okra are either polyphagous or oligophagous pests, which have many alternate hosts throughout the year. The major insect pests attack the crop, including the shoot and fruit borer, *Earias vittella* (Fabricius) & *Earias insulana* (Boisd.), fruit borer, *Helicoverpa armigera* (Hübner), whitefly, *Bemisia tabaci* (Gennadius), jassid, *Amrasca bigutulla bigutulla* (Ishida), aphid, *Aphis gossypii* Glover, leaf roller, *Sylepta derogata* (Fabricius), blister beetle *Mylabris pustulatus* Thunberg, dusky cotton bug, *Oxycarenus hyalinipennis* Costa, red cotton bug, *Dysdercus cingulatus* (Fabricius) and red spider mite, *Tetranychus urticae* Koch (Bhatt and Karnatak, 2018; Meena *et al*., 2020; Chauhan *et al*., 2023).

The borer complex of okra comprises of shoot and fruit borers *viz*., *E. vittella* and *E. insulana* is also a very destructive pest. The attack of shoot and fruit borer (*E. vittella*) on okra starts 4th to 5th weeks after germination both in *kharif* and *summer* seasons. The infested top tender shoots dry while flower, bud and developing fruit down prematurely. The infested shoots droop, wither and dry up. The holes in the fruits are filled with excrement after the larvae bore through them. Fruits with infestations get malformed and become unsafe to eat. It causes 52.33 to 75.75% fruit loss in the field. The fruit borer (*H. armigera*) is a polyphagous insect that attacks cotton, okra, tomato, chilli, cabbage, pea, pigeon pea, chickpea etc. throughout the world as well as in India. Damage is only caused by larvae. They bore the floral bud and fruits. The insects create circular openings in the fruits by penetrating through the sepals and petals, reaching the ovary to consume its contents. This action leads to the fruits wilting and eventually dropping from the plant (Pareek and Bhargava, 2003).

The sucking pest complex of okra consisting of aphids, leaf hoppers, whiteflies, thrips and mites causes 17.46% yield loss and failure to control them in initial stages was reported to cause 54.04% yield loss (Chaudhary and

Daderch, 1989). The whitefly is a significant economic threat to okra cultivation in numerous tropical and subtropical areas. As a polyphagous pest with global agricultural significance, it causes harm by feeding on sap, excreting honeydew and spreading viral diseases. Whitefly, besides causing direct damage, acts as a vector of yellow vein mosaic virus (YVMV), which is a major constraint for okra cultivation (Neeraja *et al.,* 2004). The jassids suck the cell sap from the lower surface of the leaves and inject toxic substance resulting in curling of leaves, because of which the plant growth is retarded. The sever infestation of the pest causes burning of leaves which fall later and results in 40-60% decrease in yield (Nagar *et al.,* 2017).

To avoid insect pest infestation and ensure high-quality crop yields, it's crucial to effectively manage pest populations using suitable management measures at the right time. The present study aims to assess various pre-mixed formulations against insect pest complex in okra crops (Subbireddy *et al.,* 2018).

MATERIALS AND METHODS

The variety Super Anamika was sown using the recommended agronomic practices at the Students' Instructional Farm, Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya (U.P.) during the *Kharif* season of 2023 in a Randomized Block Design (RBD) with 8 treatments and 3 replications. The plot size was 1.8 × 2.4 meters and the spacing between plant to plant and line to line was maintained at 45 cm × 30 cm. Two seeds per hill were dibbled at the depth of 4-5cm, maintaining 30 cm distance. After complete germination and establishment of plants, thinning was done to keep one plant per hill in whole experimental field. The efficacy of combination insecticides *i.e*., imidacloprid 40% + fipronil 40% WG 500 g/ha, imidacloprid 40% + ethiprole 40% WG 500 g/ha, beta-cyfluthrin 8.49% + imidacloprid 19.81% OD 400ml g/ha, profenophos 40% + cypermethrin 4% EC 1250 ml/ha, thiamethoxam 12.6% + lambda cyhalothrin 9.5% ZC 150 ml/ha, deltamethrin 0.72% + buprofezin 5.65% EC 500 ml/ha, deltamethrin 1% + triazophos 35% EC 1000 ml/ha with control (water spray) against insect pest complex of okra were tested. Crop was monitored regularly for recording the occurrence of insect pest complex. The first spray of insecticides was done 45 days after sowing and the second 25 days after first spray. Pre-treatment observation was recorded a day before spray and post treatment count was observed on 3^{rd}, 7^{th} and 15^{th} days after spraying. The population of whitefly and jassid was recorded as No. of nymphs and adults present per three leaves on 5 randomly selected plants and for the Shoot and Fruit borer per cent shoot & fruit infestation was observed. The data of shoot/fruit infestation was taken by counting infested and un-infested shoots/fruits and expressed as percentage.

The per cent reduction of the population over control (PROC) in different treatments was calculated using Henderson and Tilton's (1955) formula as given below.

Per cent efficacy = 1 - $\sqrt{x+0.5}$ x $\sqrt{x+0.5}$ 100

Where,

T_a = Population in the treated plot after spray.

T_b = Population in the treated plot before spray.

C_a = Population in the control plot after spray.

C_b = Population in the control plot before spray.

The incremental cost-benefit ratio was determined for each treatment by using formula.

Incremental Benefit Cost Ratio = $\sqrt{x+0.5}$

All the data acquired were statistically analyzed using the standard Randomized Block Design method. The population data were into a square root transformation ($\sqrt{x+0.5}$).

RESULTS AND DISCUSSION

Whitefly *(B. tabaci)*

The experiment assessing the efficacy of certain combination insecticides against whitefly revealed that the plot treated with imidacloprid 40% + fipronil 40% WG 500g/ha was recorded lowest mean population of whitefly (2.24±0.06 per 3 leaves and 1.61±0.12 per 3 leaves, 77.51% & 82.48% PROC after first and second spray, respectively), followed by imidacloprid 40% + ethiprole 40% WG 500g/ha (2.64±0.25 per 3 leaves and 1.87±0.06 per 3 leaves, 73.49% & 79.65% PROC after the first and second spray, respectively) (Table 1). In contrast, the plot treated with profenophos 40% + cypermethrin 4% EC 1250ml/ha recorded highest mean population of whitefly with lowest percent reduction over control (4.07±0.29 per 3 leaves and 3.33±0.08 per 3 leaves, 59.14% & 63.76% after first and second spray, respectively). However, the untreated plot was recorded the 9.96±0.25 per 3 leaves and 9.19±0.23 per 3 leaves. imidacloprid 40% + fipronil 40% WG offers broad-spectrum control by targeting a wide range of pests through complementary modes of action. This combination enhances effectiveness, providing superior pest control compared to using either ingredient alone. Zote *et al*. (2018) conducted a study on various doses of Solomon to control the cashew tea mosquito bug and thrips. They found that the treatment betacyfluthrin 90% + imidacloprid 210% at a concentration of 1.5 ml per 10 liters was the most effective for managing of tea mosquito bug and thrips. Kumar *et al*. (2024) also noted that combination insecticide betacyfluthrin 8.49% + imidacloprid 19.81% OD 400ml/ha was observed most effective against whitefly, Jassid and serpentine leaf miner. Yadav *et al*. (2024) also reported that imidacloprid 40% + fipronil 40% WG 500 g/ha was effective against the Brown Plant Hopper and Rice Gundhi bug. Kumar *et al.* (2019) also found that combination insecticides effectively manage sucking pests of Chilli.

Jassid (*A. biguttula biguttula*)

The efficacy of certain combination insecticides against jassid revealed that, plot treated with imidacloprid 40% + fipronil 40% WG 500g/ha was recorded lowest mean population of jassid (1.87±0.29 per 3 leaves and 1.21±0.22 per 3 leaves, 77.17% & 84.89% PROC after first and second spray, respectively), followed by imidacloprid 40% + ethiprole 40% WG 500g/ha was recorded mean population of jassid (2.19±0.22 per 3 leaves and 1.47±0.28 per 3 leaves, 73.26% & 81.65% PROC after the first and second spray, respectively) (Table 2). In contrast, the plot treated with profenophos 40% + cypermethrin 4% EC 1250ml/ha recorded highest mean population with lowest per cent reduction of jassid (3.51±0.39 per 3 leaves and 2.87±0.39 per 3 leaves, 57.14% & 64.17% PROC after first and second spray,

Table 1. Efficacy of certain combination insecticides against Whitefly, *B. tabaci* infesting okra

Tr. No.	Treatments	Dose/ha	*Population of whitefly per 3 leaves (Mean+SD)					
			First Spray			Second Spray		
			DBS	After Spray	PROC	DBS	After Spray	PROC
T_1	Imidacloprid 40% + Fipronil 40% WG	500g	7.36±0.25 (2.80)	2.24±0.06 (1.66)	77.51	3.96±0.34 (2.11)	1.61±0.12 (1.45)	82.48
T_2	Imidacloprid 40% + Ethiprole 40% WG	500g	7.91±0.39 (2.90)	2.64±0.25 (1.77)	73.49	4.09±0.23 (2.14)	1.87±0.06 (1.54)	79.65
T_3	Beta-cyfluthrin 8.49% + Imidacloprid 19.81% OD	400mL	7.82±0.23 (2.88)	2.93±0.04 (1.85)	70.58	4.29±0.17 (2.19)	2.26±0.06 (1.66)	75.41
T_4	Profenophos 40% + Cypermethrin 4% EC	1250mL	7.02±0.34 (2.74)	4.07±0.29 (2.14)	59.14	4.44±0.34 (2.22)	3.33±0.08 (1.96)	63.76
T_5	Thiamethoxam 12.6% + Lambda Cyhalothrin 9.5% ZC	150mL	8.04±0.27 (2.92)	3.33±0.11 (1.96)	66.57	4.31±0.20 (2.19)	2.59±0.07 (1.76)	71.82
T_6	Deltamethrin 0.72% + Buprofezin 5.65% EC	500mL	7.73±0.33 (2.87)	3.88±0.32 (2.09)	61.04	4.42±0.34 (2.22)	3.04±0.17 (1.88)	66.92
T_7	Deltamethrin 1% + Triazophos 35% EC	1000mL	7.78±0.38 (2.88)	3.59±0.13 (2.02)	63.96	4.38±0.23 (2.21)	2.80±0.17 (1.82)	69.53
T_8	Control (Water spray)	-	8.02±0.38 (2.92)	9.96±0.25 (3.23)	-	8.04±0.30 (2.92)	9.19±0.23 (3.11)	-
	SEm±		**-**	**(0.03)**	**-**	**(0.02)**	**(0.02)**	**-**
	CD at 5%		**(NS)**	**(0.08)**	**-**	**(0.07)**	**(0.06)**	**-**

Figures in the parenthesis are $\sqrt{x} + 0.5$ transformed values, DBS= Day before spray, DAS= Days after spray, *Mean of three replications, PROC= Per cent reduction over control

Table 2. Efficacy of certain combination insecticides against Jassid, *A. biguttulla biguttulla* infesting okra

Tr. No.	Treatments	Dose/ha	*Population of jassid per 3 leaves (Mean+SD)					
			First Spray			Second Spray		
			DBS	After Spray	PROC	DBS	After Spray	PROC
T_1	Imidacloprid 40% + Fipronil 40% WG	500g	6.44±0.56 (2.64)	1.87±0.29 (1.54)	77.17	3.27±0.23 (1.94)	1.21±0.22 (1.31)	84.89
T_2	Imidacloprid 40% + Ethiprole 40% WG	500g	6.47±0.20 (2.64)	2.19±0.22 (1.64)	73.26	3.56±0.30 (2.01)	1.47±0.28 (1.41)	81.65
T_3	Beta-cyfluthrin 8.49% + Imidacloprid 19.81% OD	400mL	6.36±0.23 (2.62)	2.50±0.28 (1.73)	69.47	3.69±0.23 (2.05)	1.74±0.35 (1.50)	78.28
T_4	Profenophos 40% + Cypermethrin 4% EC	1250mL	6.51±0.41 (2.65)	3.51±0.39 (2.00)	57.14	4.24±0.17 (2.18)	2.87±0.39 (1.83)	64.17
T_5	Thiamethoxam 12.6% + Lambda Cyhalothrin 9.5% ZC	150mL	6.20±0.29 (2.59)	2.96±0.33 (1.86)	63.86	3.80±0.12 (2.07)	2.19±0.30 (1.64)	72.66
T_6	Deltamethrin 0.72% + Buprofezin 5.65% EC	500mL	6.64±0.38 (2.67)	3.36±0.35 (1.96)	58.97	3.98±0.33 (2.12)	2.76±0.40 (1.81)	65.54
T_7	Deltamethrin 1% + Triazophos 35% EC	1000mL	6.24±0.34 (2.60)	3.18±0.15 (1.92)	61.17	3.87±0.29 (2.09)	2.47±0.39 (1.72)	69.16
T_8	Control (Water spray)	-	6.33±0.24 (2.61)	8.19±0.24 (2.95)	-	7.16±0.27 (2.77)	8.01±0.30 (2.92)	-
	SEm±		**-**	**(0.03)**	-	**(0.03)**	**(0.03)**	-
	CD at 5%		**(NS)**	**(0.08)**	-	**(0.08)**	**(0.09)**	-

Figures in the parenthesis are $\sqrt{x} + 0.5$ transformed values, DBS= Day before spray, DAS= Days after spray, *Mean of three replications, PROC= Per cent reduction over control

respectively). However, the untreated plot was recorded the 8.19±0.24 per 3 leaves and 8.01±0.30 per 3 leaves. imidacloprid 40% + fipronil 40% WG provides broad-spectrum control, effectively targeting a wide array of pests through its complementary modes of action. This combination increases effectiveness, delivering better pest control than using either ingredient separately. Furthermore, it supports resistance management by employing two distinct modes of action, which helps delay the onset of pest resistance. Kumar *et al*. (2024) also noted that combination insecticide betacyfluthrin 8.49% + imidacloprid 19.81% OD 400ml/ha was observed most effective against whitefly, Jassid and serpentine leaf miner. Yadav *et al*. (2024) also reported that imidacloprid 40% + fipronil 40% WG 500 g/ha was effective against the Brown Plant Hopper and Rice Gundhi bug.

Shoot & fruit borer (*E. vittella*)

The data regarding the efficacy of certain combination insecticides against shoot & fruit borer revealed that the plot treated with imidacloprid 40% + fipronil 40% WG 500g/ha was recorded lowest mean damage (3.40±0.13 per cent shoot damage and 2.61±0.07 per cent fruit damage, 71.36% & 78.87% PROC after first and second spray, respectively) followed by beta-cyfluthrin 8.49% + imidacloprid 19.81% OD 400ml/ha (3.77±0.15 per cent shoot damage and 2.91±0.27 per cent fruit damage, 68.24% & 76.44% PROC after the first and second spray, respectively). In contrast, the plot treated with deltamethrin 0.27% + buprofezin 5.65% EC 500ml/ha recorded highest mean damage (5.26±0.12 per cent shoot damage and 4.39±0.08 per cent fruit damage, 55.69% & 64.45% PROC after first and second spray, respectively). However, the untreated plot was recorded the (11.87±0.19 per cent shoot damage and 12.35±0.15 per cent fruit damage) (Table 3). imidacloprid 40% + fipronil 40% WG offers a powerful tool for pest control. This formulation leverages the strengths of both insecticides, providing a broader spectrum of activity, enhancing efficacy through synergistic effects, and aiding in resistance management. Donawade *et al.,* (2020) evaluated insecticides against sugarcane top shoot borer (*S. excerptalis*) and found Chlorantraniliprole 18.5 SC to be the most effective treatment fipronil 5 SC was the second most effective. Kumar *et al*. (2024) also noted imidacloprid 40%+fipronil 40% WG 500 g/ha second most effective treatment against tomato fruit borer (*H. armigera*).

Effect of Treatments on Yield of Okra

The crop yields showed significant differences among all the treatments. The highest yield was recorded in plot treated with imidacloprid 40% + fipronil 40% WG 500g/ha, producing 95.27 q/ha (Table 4). This was followed closely by betacyfluthrin 8.49% + imidacloprid 19.81% OD 400ml/ha, which resulted in a yield of 93.67 q/ha. The lowest yield was observed with deltamethrin 0.27% + buprofezin 5.65% EC 500ml/ha, which produced 78.60 q/ha. The combination insecticide delivers higher yields by effectively targeting a broad range of pests with its dual-action formula. This enhances pest control, ensures healthier crops, and reduces the risk of pest resistance, leading to improved plant health and increased productivity. Studies and trials have shown that fields treated with this combination experience significantly higher yields compared to those treated with single-ingredient insecticides. The results of the present study are in accordance with findings of Sreenivas *et al.* (2019), who reported that the highest fruit yield was recorded in the

Table 3. Efficacy of certain combination insecticides against Shoot & fruit borer, *E. vittella* infesting okra

Tr. No.	Treatments	Dose/ha	*Per cent Shoot & fruit borer damage (Mean+SD)					
			Shoot damage			Fruit damage		
			First Spray			Second Spray		
			DBS	Mean	PROC	DBS	Mean	PROC
T_1	Imidacloprid 40% + Fipronil 40% WG	500g	10.58±0.22 (3.33)	3.40±0.13 (1.97)	71.36	9.78±0.25 (3.21)	2.61±0.07 (1.76)	78.87
T_2	Imidacloprid 40% + Ethiprole 40% WG	500g	10.24±0.21 (3.28)	4.43±0.21 (2.22)	62.68	9.88±0.17 (3.22)	3.51±0.18 (2.00)	71.58
T_3	Beta-cyfluthrin 8.49% + Imidacloprid 19.81% OD	400mL	10.49±0.57 (3.31)	3.77±0.15 (2.07)	68.24	9.69±0.20 (3.19)	2.91±0.27 (1.85)	76.44
T_4	Profenophos 40% + Cypermethrin 4% EC	1250mL	10.18±0.30 (3.27)	4.84±0.19 (2.31)	59.22	9.94±0.23 (3.23)	3.72±0.25 (2.05)	69.88
T_5	Thiamethoxam 12.6% + Lambda Cyhalothrin 9.5% ZC	150mL	10.37±0.36 (3.30)	4.05±0.15 (2.13)	65.88	9.52±0.25 (3.17)	3.18±0.15 (1.92)	74.25
T_6	Deltamethrin 0.72% + Buprofezin 5.65% EC	500mL	10.59±0.38 (3.33)	5.26±0.12 (2.40)	55.69	9.76±0.24 (3.20)	4.39±0.08 (2.21)	64.45
T_7	Deltamethrin 1% + Triazophos 35% EC	1000mL	10.28±0.24 (3.28)	5.21±0.21 (2.37)	56.87	9.63±0.31 (3.18)	4.15±0.09 (2.16)	66.40
T_8	Control (Water spray)	-	10.60±0.21 (3.33)	11.87±0.19 (3.53)	-	10.01±0.28 (3.24)	12.35±0.15 (3.58)	-
	SEm±		**-**	**(0.02)**	**-**	**(0.02)**	**(0.02)**	**-**
	CD at 5%		**(NS)**	**(0.07)**	**-**	**(0.06)**	**(0.07)**	**-**

Figures in the parenthesis are $\sqrt{x} + 0.5$ transformed values, DBS= Day before spray, DAS= Days after spray, *Mean of three replications, PROC= Per cent reduction over control

Table 4: Economics of certain combination insecticides against insect pest complex in okra

Tr. No.	Treatments	Dose/ha	Yield (q/ha)	Incremental B:C ratio	Rank
T_1	Imidacloprid 40% + Fipronil 40% WG	500g	95.27	4.90	VI
T_2	Imidacloprid 40% + Ethiprole 40% WG	500g	90.63	3.33	VII
T_3	Beta-cyfluthrin 8.49% + Imidacloprid 19.81% OD	400mL	93.67	17.12	II
T_4	Profenophos 40% + Cypermethrin 4% EC	1250mL	81.27	11.91	V
T_5	Thiamethoxam 12.6% +Lambda Cyhalothrin 9.5% ZC	150mL	86.57	21.21	I
T_6	Deltamethrin 0.72% + Buprofezin 5.65% EC	500mL	78.60	13.01	IV
T_7	Deltamethrin 1% + Triazophos 35% EC	1000mL	85.83	15.15	III
T_8	Control (Water spray)	-	60.13	-	-

Prevailing market price of okra during 2023 = 22/kg, Labour charge = 300/day/labour, Sprayer charge =100/day, two sprays performed during entire crop season

imidacloprid 17.8 SL 0.30 spray treatment, which yielded 109.99 and 108.66 q/ha in Raichur and Bidar, respectively.

Incremental Cost-Benefit Ratio of Treatments

The highest net return of Rs. 69,701 per hectare was found in plot treated with betacyfluthrin 8.49% + imidacloprid 19.81% OD 400 ml/ha, followed by net return of Rs. 64,193 per hectare was found in plot treated with imidacloprid 40% + fipronil 40% WG 500 g/ha (Table 4). The lowest net return of Rs. 37,727 per hectare observed in plot treated with deltamethrin 0.27% + buprofezin 5.65% EC 500 ml/ha. However, the most effective and economical treatment thiamethoxam 12.6% + lambda cyhalothrin 9.5% ZC 150 ml/ha found with incremental benefit-cost ratio of 1:21.21.

CONCLUSION

Based on the results of this study, the combination insecticide imidacloprid 40% + fipronil 40% WG 500g/ha proved to be the most effective treatment in managing whitefly, jassid, and shoot & fruit borer, consistently recording the lowest pest populations and damage across all observations, resulting in the highest okra yield of 95.27 q/ha. Moreover, the economic analysis highlighted the highest net return for betacyfluthrin 8.49% + imidacloprid 19.81% OD 400ml/ha, suggesting this treatment is economically viable while maintaining effective pest control. In conclusion, the combination insecticides, particularly imidacloprid 40% + fipronil 40% WG and betacyfluthrin 8.49% + imidacloprid 19.81% OD, are highly effective for managing pests, improving crop yields, and offering better economic returns, making them valuable tools in integrated pest management programs.

ACKNOWLEDGEMENTS

The authors are highly thankful to the Department of Entomology, Acharya Narendra deva University of Agriculture & Technology, Kumarganj, Ayodhya, Uttar Pradesh, India.

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MS Received: 28 March 2025
MS Acceptance: 16 May 2025

Pest Management in Horticultural Ecosystems
Vol. 31, No.1 pp 42-47 (2025) DOI Number : 10.5958/0974-4541.2025.00020.8

Status of bondar nesting whitefly (*Paraleyrodes bondari* Peracchi) on coconut in Konkan region of Maharashtra

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ABSTRACT: Roving surveys for coconut Bondar nesting whitefly (BNW), *Paraleyrodes bondari* Peracchi were carried out in at monthly interval in Ratnagiri District of Maharashtra during 2022 to 2024 and incidence and intensity of BNW was worked out. The observations revealed that April month had the maximum incidence (19.8%), intensity (18.6%) and live colonies (32.1) of bondar nesting whitefly whereas minimum incidence (5.4%), intensity (2.6%) and live colonies (8.43) were observed during July. It was inferred that the infestation of BNW increased after rainy season and attend peak during November-October and April-May during high temperature. The maximum temperature was positively significant correlated with incidence, intensity and no. of live colonies/leaflet of BNW. However, rainfall and relative humidity (morning and afternoon) was negatively significant correlated with incidence, intensity and no. of live colonies/leaflet of BNW. The minimum temperature was negative correlated with incidence, intensity and no. of live colonies/leaflet of BNW.

Keywords: Bondar whitefly, coconut, Maharashtra, population dynamics

INTRODUCTION

Coconut is an important plantation crop in the southern and coastal states. It occupied 43,320 hector area in Maharashtra and 22,750 hector area in the Konkan region of Maharashtra. It is the most versatile tree crop cultivated in the tropics providing livelihood and employment securities to the rural region. The agricultural economy of India is vulnerable to the threat posed from the introduction of exotic pests/diseases. Mandal (2011) listed 116 exotic insect species in India. Among the insect pests, exotic whiteflies have invaded several countries causing direct losses in agriculture, horticulture and forestry. Currently, there are 442 species of whiteflies belonging to 63 genera known from India; of these, a few are economically important (Karthick *et al*., 2018). The presence of Rugose Spiraling Whitefly (RSW), *Aleurodicus rugioperculatus* Martin (Hemiptera: Aleyrodidae) in India in coconut plantations was reported across Kerala, Tamil Nadu, Karnataka, and Andhra Pradesh States in 2016-2017 (Shanas *et al.,* 2016, Sundararaj and Selvaraj, 2017). Yield losses of up to 45 per cent were reported (Kalidas, 2019).

In recent years, an invasive whitefly, Bondar's nesting whitefly (*Paraleyrodes bondari* Peracchi) found in coexist with *A. rugioperculatus* feeding exclusively on coconut leaflets. In India it was reported for the first time, from Kayamkulam, Kerala (Joseph Rajkumar *et al*., 2019). The occurrence of egg clusters at creamy yellow nymphs with prominent Bre glass strands from the dorsum and single thick flagellum, characteristic nest-like woolly wax around the pupa. Adults are smaller in size (0.95 mm) than the rugose whitefly with conspicuous oblique grey bands forming a typical "X" pattern and construct unique woolly wax nests (hence the name nesting whitefly) on palm leaflets' abaxial surface (Joseph Rajkumar *et al*., 2019). The adaptation trait of the whiteflies to changing climate and to the new host is the key factor in their spatiotemporal distribution. The polyphagous nature of the non-native BNW warrants stringent quarantine protocols to prevent its further spread to other coconut growing areas. The nesting whitefly population was observed to increase phenomenally on oil palm during 2021 to 2022, a 100 per cent palm infestation was observed (Chalapati *et al*., 2023). The occurrence, diversity, and how this is impacted by host and variety variability, geographical dispersion, and environmental variability of whiteflies in India are unknown. Because this is a relatively new whitefly species. Hence, present studies were conducted to study the severity of its infestations, impact on coconut cultivation and relation to weather factors in Konkan region of Maharashtra.

MATERIALS AND METHODS

Studies on surveillance and assessment of bondar nesting whitefly, *P. bondari* on coconut were carried out at All india Coordinated Project (AICRP) on Plantation Crops, Regional Coconut Research Station, Bhatye in the District of Ratnagiri in Maharashtra, India during 2022 to 2024. Roving survey were undertaken in three coconut gardens at monthly interval. Four-to-six-year aged coconut five palms in each location were selected for recording the observations. Per cent incidence of BNW on leaves /palms was calculated by recording number of leaves infested by BNW/total leaf per palm x100. Per cent intensity of pest damage from three pest infested leaves per palm from the outer/middle whorl representing three directions (no. of leaflets infested by BNW/total leaflets per leaf). Four leaflets from each observed sample leaf (total of 4 leaflet/palm (20 leaflets/plot) were collected and brought to laboratory for assessment of live colonies *viz.,* eggs, nymphs, adults and natural enemies like spiders and predators. The generated data were subjected for statistical analysis.

The severity of infestation was categorized as below.

- High >20 live BNW colonies/leaflet (Grade 3)
- Medium10-20 live BNW colonies/leaflet (Grade 2)
- Low < 10 live BNW colonies/leaflet (Grade1)
- No colony (Grade 0)

RESULTS AND DISCUSSION

The data presented in Table 1 indicated that the incidence of bondar nesting whitefly (BNW) was noticed in the range of 6.50 to 24.6 per cent. However, intensity of BNW was recorded 2.30 to 12.3 per cent from January to December 2022. The maximum incidence and intensity of BNW were recorded 24.6 and 12.3 per cent, respectively in April 2022 and December 2022, respectively. Whereas minimum incidence (6.50%) and intensity (2.30%) was observed in July 2022. The highest live population of BNW (33.7 nos.) was found in November 2022. Whereas, lowest was observed in July 2022. The low grade index was observed during the year. The average BNW pest records *viz.,* incidence, intensity, grade index and no. of live colonies were recorded 17.3, 7.27, 0.58 and 16.5/leaflet, respectively. The mean population of natural enemies like spiders and predators was noticed 0.55 and 0.20 per leaflet during the period.

The incidence of bondar nesting whitefly (BNW) was noticed in the range of 4.83 to 18.1 per cent (Table 2). The intensity of BNW was recorded 3.59 to 21.6 per cent between January and December 2023. The maximum incidence and intensity of BNW were observed 18.1 and 21.6 per cent in March 2023, respectively. The least

Table 1. Extent of infestation of Bondar Nesting whitefly (BNW) in coconut and their natural enemies (2022)

Month	Incidence (%)	Intensity (%)	Grade Index	No. of live colonies/leaflet	Natural Enemies
January	16.6	7.38	0.53	13.7	0.93
February	18.2	8.00	0.52	14.4	0.46
March	15.3	6.72	0.53	13.3	0.40
April	24.6	10.2	0.63	17.0	0.33
May	14.4	5.74	0.52	17.2	0.20
June	14.4	6.01	0.37	11.6	0.46
July	6.50	2.30	0.35	9.60	0.80
August	24.0	5.48	0.58	11.9	0.53
September	19.4	5.25	0.55	13.3	0.67
October	21.4	5.62	0.70	18.4	0.73
November	17.3	12.2	0.92	33.7	0.60
December	16.1	12.3	0.70	24.2	0.47
Mean ± SE	17.3 ± 1.46	7.27 ± 0.90	0.58 ± 0.05	16.5 ± 2.0	0.55 ± 0.06

Table 2. Extent of infestation of Bondar Nesting whitefly (BNW) in coconut and their natural enemies (2023)

Month	Incidence (%)	Intensity (%)	Grade Index	No. of live colonies *	Natural Enemies **
January	16.9	20.7	1.11	38.8	1.13
February	17.7	21.2	1.25	41.7	0.93
March	18.1	21.6	1.30	43.6	1.20
April	17.0	19.4	0.86	32.2	0.86
May	15.9	18.4	0.81	30.8	0.73
June	13.9	16.4	0.75	28.3	0.60
July	5.64	3.69	0.35	10.8	0.40
August	4.83	3.59	0.30	9.40	0.40
September	5.64	3.86	0.35	12.2	0.40
October	7.2	6.61	0.45	16.5	0.40
November	16.2	20.2	0.98	31.1	0.40
December	14.7	15.4	0.94	27.6	0.33
Mean ± SE	12.8 ± 1.6	14.3 ± 2.3	0.8 ± 0.1	26.9 ± 3.6	0.6 ± 0.1

*Live colony/ four leaflets /palm; **Natural enemies/ four leaflets/ palm

intensity (3.59%) and incidence (4.83%) was observed in August 2023. The medium grade index was observed during January to Manch months 2023 and rests of the months noticed low grade index. The maximum live colonies of BNW (43.6 nos.) were recorded in March 2023. Whereas, lowest (9.40 nos.) was found in August 2023. The average BNW pest records viz., incidence, intensity, grade index and no. of live colonies were recorded 12.8, 14.3, 0.80 and 26.9/four leaflet, respectively. The mean population of natural enemies like spiders and predators ranged from 0.2 to 0.93 per four leaflets.

The data presented in Table 3 indicated that the incidence of bondar nesting whitefly (BNW) was noticed in the range of 2.44 to 17.9 per cent. However, intensity of BNW was recorded 1.84 to 26.1 per cent from January to December 2024. The maximum incidence and intensity of BNW were recorded 17.9 and 26.1 per cent in April 2024, respectively. Whereas minimum incidence (2.44%) and intensity (1.84%) was observed in August 2024. The low grade index was observed during the year except April 2024 which recorded medium grade index (1.18). The maximum live colonies of BNW (47.2 nos.) were observed in April 2024. Whereas minimum (4.10 nos.) was noticed in August 2024. The average BNW pest records viz., incidence, intensity, grade index and no. of live colonies were recorded 10.5, 11.9, 0.65 and 22.5/four leaflet, respectively. The mean population of natural enemies like spiders and predators varied from 0.4 to 1.13 per four leaflets during the period.

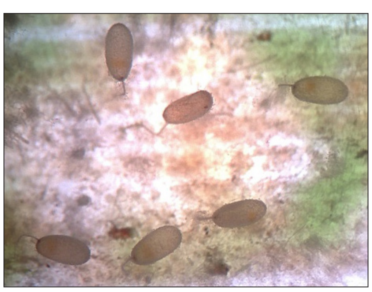

Plate 1. Eggs of Bondar nesting whitefly

Plate 2. Pupa of Bondar nesting whitefly

Plate 3. Nymph of Bondar nesting whitefly

Plate 4. Live colony of Bondar nesting whitefly

Plate 5. Incidence of Bondar nesting whitefly (BNW) on coconut

Table 3. Extent of infestation of Bondar Nesting whitefly (BNW) and its natural enemies in coconut (2024)

Month	Incidence (%)	Intensity (%)	Grade Index	No. of live colonies *	Natural Enemies **
January	14.9	21.5	0.85	29.0	0.50
February	12.4	18.4	0.78	27.4	0.40
March	15.8	22.5	0.98	36.8	0.60
April	17.9	26.1	1.18	47.2	0.80
May	12.2	13.7	0.70	22.9	0.50
June	8.30	5.29	0.53	17.0	0.20
July	3.91	1.92	0.20	4.90	0.10
August	2.44	1.84	0.18	4.10	0.10
September	6.29	4.85	0.38	11.1	0.20
October	9.81	8.24	0.60	18.2	0.20
November	10.9	8.90	0.63	22.4	0.30
December	11.7	9.93	0.80	29.7	0.30
Mean ± SE	10.5 ± 1.4	11.9 ± 2.5	0.65 ± 0.09	22.5 ± 3.8	0.35 ± 0.06

*Live colony/ four leaflets /palm; **Natural enemies/ four leaflets/ palm

Overall data during 2022-24 depicted in Table 4 revealed that the maximum incidence (19.8%), intensity (18.6%) and live colonies of BNW (32.1) of bondar nesting whitefly were recorded in April month. Whereas, minimum incidence (5.4%), intensity (2.6%) and live colonies of BNW (8.43) were observed in July month on lower leaves of dwarf varieties of coconut. It was also noticed that the infestation of BNW increased after rainy season. and attend peak during November-October and April-May in high temperature. Wankhede *et al.* (2021) found that the indicated that the incidence (31.9%) and intensity (18.1%) of RSW had increased during the rainy season. Sundararaj and Selvaraj (2017) were observed the infestation was very severe on lower leaves as compared to that of the middle and upper young leaves in dwarf and hybrid coconut palm which are about four to six years old. Its infestation increased after over of rainy season were recorded 12.8 and 6.8 per cent, respectively in October. Later on, its increasing trends showed up to December, which noticed 14.2 and 12.5 per cent, respectively. Srinivasan *et al.* (2016) reported that prolonged dry spell during June to September 2016, after deficit rainfall (69 %) coupled with decreased relative humidity seem to favour the spread of the pest in coconut plantations of Pollachi tract of Tamil Nadu, India. January onwards, its populations was initiated and after that it gradually declined. In the month of April its populations attained a major peak (Incidence 19.8% and Intensity 18.6%) with increased of temperature. Bondar nesting whitefly live population was noticed maximum in the month of April (32.1 nos.). Whereas the lowest population was recorded in July (8.43 nos.). Spiders and

Table 4. Overall mean infestation of coconut BNW and its correlation with weather factors during 2022-24

Month	Incidence of BNW (%)	Intensity of BNW (%)	No. of live colonies/ leaflet	Max. Temperature (°C)	Min. Temperature (°C)	Morning Humidity (%0)	Evening Humidity (%0)	Rainfall (mm)
January	16.1	16.5	27.1	31.6	19.0	72.0	55.8	9.4
February	16.1	15.9	27.8	33.3	19.2	64.7	55.3	0.0
March	16.4	16.9	31.2	33.8	22.5	64.8	57.2	0.0
April	19.8	18.6	32.1	33.6	24.8	73.4	63.1	2.1
May	14.2	12.6	23.6	33.8	26.3	72.3	66.2	24.3
June	12.2	9.2	18.9	31.9	25.5	83.8	77.2	779.2
July	5.4	2.6	8.43	29.0	24.6	89.5	87.3	1341.2
August	10.4	3.6	8.47	29.8	24.7	87.5	82.4	567.5
September	10.4	4.7	12.2	31.0	24.8	88.0	80.2	338.8
October	12.8	6.8	17.7	32.5	23.9	81.5	74.9	209.9
November	14.8	13.8	29.0	35.2	23.3	62.0	58.6	11.8
December	14.2	12.5	27.1	34.0	21.4	63.8	57.3	0.0
Correlation Coefficient (r)								
mx t	0.769	0.761	0.869					
min t	-0.380	-0.495	-0.461					
mh	-0.743	-0.842	-0.904					
eh	-0.842	-0.921	-0.937					
rain	-0.864	-0.771	-0.800					
R-Value		0.68						

predators were observed maximum during April, and their population were increased after October onwards. The data is confirmed with the finding of Wankhede *et al.* (2021). Mondal *et al*. (2020) revealed a high population of Neuropteran predators, few parasitoids and some Phytoseiid mites as natural enemies for the rugose spiralling whitefly in coconut. A similar observation on the concomitant occurrence of RSW and nesting whiteflies was reported by previous researchers on coconut from Southern parts of India (Chandrika *et al*., 2017; Vidya *et al*., 2019). The feeding damage of BNW has lesser than RSW with minimum honeydew and sooty mold deposits. Suriya *et al*. (2024) conducted surveys to assess the intensity of damage caused by the *Paraleyrodes bondari* Peracchi in coconut, poses a significant threat to coconut crops, affecting both yield and overall plant health. The nesting whitefly population was observed to increase phenomenally on oil palm and within a year i.e., from 2021 to 2022, the intensity per palm increased by 24.49 per cent and per leaf increased by 63.28 per cent by Chalapati *et al*. (2023).

The maximum temperature was positively correlated with incidence, intensity and no. of live colonies/leaflet of BNW. However, rainfall was negatively correlated with incidence, intensity and no. of live colonies/ leaflet of BNW. Wankhede *et al.* (2021) observed that the maximum temperature had positive impact on the incidence and intensity of RSW. However, intensity of RSW was negatively correlated with rainfall and evening humidity. The minimum temperature was negatively correlated with incidence, intensity and no. of live colonies/leaflet of BNW.

From the results of the study, it can be cocluded that the infestation of BNW increased after rainy season and attend peak during November-October and

April-May during high temperature. The maximum temperature was positively significant correlated with incidence, intensity and no. of live colonies/leaflet of BNW. However, rainfall and relative humidity (morning and afternoon) was negatively significant correlated with incidence, intensity and no. of live colonies/leaflet of BNW.

ACKNOWLEDGEMENT

The authors are thankful to ICAR-AICRP (Plantation Crops) for providing funds, technical help and also thankful to DBSKKV, Dapoli for reviewing the research work and guidance for conduct of surveys.

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MS Received: 12 May 2025
MS Acceptance: 10 June 2025

Pest Management in Horticultural Ecosystems
Vol. 31, No.1 pp 48-52 (2025)
DOI Number : 10.5958/0974-4541.2025.00009.9

Greenhouse evaluation of microbial consortia against sucking pest complex of chilli (*Capsicum annuum* L.)

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ABSTRACT: The present study evaluated the greenhouse efficacy of microbial consortia comprising actinobacteria, *Pseudomonas* spp. and arbuscular mycorrhizal fungi (AMF) against the major sucking pest complex of chilli (*Capsicum annuum* L.), including thrips (*Scirtothrips dorsalis*), aphids (*Aphis gossypii*), and whiteflies (*Bemisia tabaci*). The experiment was conducted in a completely randomized design with twelve treatments, including individual and combined microbial formulations and a chemical check (Diafenthiuron 50% WP). Insects were artificially introduced, and pest counts were recorded at 30, 60, and 90 days after transplanting. Among all treatments, the microbial consortium T5 (DBT 64 + AUDT 502 + AUDP 279) consistently showed the highest suppression of all three pest species—reducing thrips, whiteflies, and aphids by 56.96%, 64.55%, and 48.78%, respectively. This efficacy is attributed to synergistic effects enhancing induced systemic resistance (ISR) and secondary metabolite production. While the insecticide achieved maximum suppression, microbial treatments offered comparable results with long-term ecological benefits. *Lecanicillium lecanii* also showed promising biocontrol potential under controlled conditions. The findings demonstrate that microbial consortia are effective, eco-friendly alternatives for managing sucking pests in chilli and hold strong potential for integration into sustainable pest management frameworks.

Keywords: Chilli (*Capsicum annuum*), sucking pests, microbial consortia, actinobacteria, induced systemic resistance (ISR), integrated pest management (IPM).

INTRODUCTION

Chilli (*Capsicum annuum* L.) is a commercially important spice and vegetable crop in India, valued for its pungency, flavor, and nutritional attributes. India is the world's largest producer and exporter of chilli, contributing nearly 38% to the global production with a cultivated area exceeding 0.75 million hectares (Anonymous, 2021). However, chilli cultivation faces significant threats from a complex of sap-sucking insect pests, particularly thrips (*Scirtothrips dorsalis*), aphids (*Aphis gossypii*), and whiteflies (*Bemisiatabaci*), which cause direct injury through cell laceration and sap extraction, as well as indirect losses by transmitting viruses such as the chilli leaf curl virus and causing "murda" disease. Thrips, especially *Thrips parvispinus* and *Scirtothrips dorsalis*, have emerged as devastating pests in recent years. Their feeding causes silvering, curling, necrosis, and defoliation, significantly impacting flower retention and fruit formation. Yield losses of up to 85% have been reported under severe infestations (Prasannakumar et al., 2021). Losses ranging from 40 to 90% have been documented depending on pest density, cultivar susceptibility, and management practices (Kurbett et al., 2018). Since past, these pests have been managed through the frequent application of chemical insecticides, often leading to environmental concerns, pesticide residues, pest resurgence, and resistance development. Overuse of insecticides has also negatively impacted beneficial arthropods, including coccinellids and parasitoids, thereby weakening natural control mechanisms (Wade et al., 2020).In recent years, plant growth-promoting rhizobacteria (PGPRs) and endophytic actinobacteria have emerged as eco-friendly alternatives. These microbes enhance plant health not only by facilitating nutrient uptake and growth but also by triggering induced systemic resistance (ISR) and producing secondary metabolites with insecticidal and deterrent effects. Among these, *Streptomyces* spp., *Pseudomonas* spp. and arbuscular mycorrhizal fungi (AMF) such as *Glomus fasciculatum* have demonstrated potential across several crops, yet their role in managing chilli sucking pests under greenhouse conditions remains underexplored. Actinobacteria are known to activate jasmonic acid and ethylene-mediated ISR pathways, enhancing the expression of defense-related enzymes such as peroxidase, polyphenol oxidase, and β-1,3-glucanase (Harun-Or-Rashid and Chung, 2017). In parallel, they produce secondary metabolites like phenazines, siderophores, and antibiotics that directly inhibit pest development and feeding (Aggarwal *et al.,* 2016). Notably, endophytic *Streptomyces* strains have demonstrated gut toxicity and feeding inhibition in *Spodoptera littoralis*, linked to metabolites such as diazinon and 4-nitrophenol (Diab et al., 2023), indicating their cross-spectrum potential against both chewing and sucking insect pests.Despite these advances, the potential of actinobacteria and PGPRs, particularly in microbial consortia, remains largely under-investigated in chilli pest management. This study was therefore undertaken to evaluate the efficacy of microbial consortia involving actinobacteria, AMF, and *Pseudomonas* spp. against the major sucking pest complex under greenhouse conditions, with the aim of developing an integrated, residue-free, and sustainable pest management strategy.

MATERIALS AND METHODS

The study was conducted during Rabi 2023 under greenhouse conditions at the Department of Entomology, University of Agricultural Sciences, Dharwad. Chilli seeds were primed by soaking them in the grown cultures of individual microbial isolates. The suspensions were incubated for 10 minutes to facilitate attachment of bacterial cells to the seed coat. Subsequently, the seeds were air-dried as described by Ramanathan et al. (2000).Primed seeds were raised in nursery trays and transplanted into pots 35 days after sowing (DAS). The experiment was laid out in a Completely Randomized Design (CRD) and included twelve treatments: T1 – *Streptomyces* spp. DBT-64 (1×10□ cfu/g) at 20 mL/L; T2 – *Streptomyces* spp. AUDT-626 (1×10□ cfu/g) at 20 mL/L; T3 – *Streptomyces* spp. AUDT-502 (1×10□ cfu/g) at 20 mL/L; T4 – *Pseudomonas* spp.AUDP-279 (1×10□ cfu/g) at 20 mL/L; T5 –DBT-64 + AUDT-502 + AUDP-279; T6 –AUDT-626 + AUDT-502 + AUDP-279; T7 –DBT-64 + AUDT-502 + AUDP-279 + arbuscular mycorrhizal fungi (AMF); T8 –AUDT-626 + AUDT-502 + AUDP-279 + AMF; T9 – AMF (*Glomus fasciculatum*); T10 – *Lecanicilliumlecanii* (2×10□ cfu/g) at 2 g/L; T11 – Diafenthiuron 50% WP at 1.0 g/L; and T12 – untreated controlwith three replications each. The crop was maintained following recommended agronomic practices. Treatments were imposed twice: first at 10 days after transplanting (DAT) and again at 45 DAT.Actinobacterial and mycorrhizal formulations were applied as soil drenches, while *L.lecanii* and Diafenthiuron 50% WP were sprayed using a knapsack sprayer. Populations of thrips (*S. dorsalis*), aphids (*A. gossypii*), and whiteflies (*B.tabaci*) were artificially established by releasing insects reared on untreated chilli potted plants maintained under insecticide-free conditions. Insect release was carried out 10 DAT.

Data Recording and Analysis

Observations on insect populations were recorded from top, middle, and lower leaves of randomly selected plants in each replication. Data were recorded at 30, 60, and 90 days after transplanting. Insect count data were subjected to square root transformation prior to statistical analysis. The data were analyzed using analysis of variance (ANOVA) following the procedure described by Gomez and Gomez (1984). Percent reduction over the untreated control was calculated using the formula proposed by Henderson and Tilton (1955).

RESULTS AND DISCUSSION

Efficacy of microbial inoculants and consortia against chilli sucking pests under greenhouse conditions

The present study evaluated the efficacy of actinobacterial isolates, *Pseudomonas* spp., arbuscular mycorrhizal fungi (AMF), and their consortia against major sucking pests of chilli under greenhouse conditions. Observations recorded at 30, 60 and 90 days after transplanting (DAT),revealed significant variations in pest populations across treatments.

Efficacy of microbial inoculants and consortia against thrips, *S. dorsalis*

Significant differences in thrips populations were observed across treatments (Table 1). Among microbial consortia, T5 (DBT 64 + AUDT 502+ AUDP 279) recorded the lowest mean thrips population at harvest (1.77) with a 56.96% reduction over the untreated control. This was followed by T6 (AUDT 626+AUDT 502+ AUDP 279) (53.13%), T7 (DBT 64 + AUDT 502+ AUDP 279+AMF) (51.28%), and T8 (AUDT 626+ AUDT 502+ AUDP 279+ AMF) (49.41%). Individual microbial treatments showed moderate efficacy: T3 (39.04%), T1 (37.95%), T2 (35.98%), and T4 (37.07%). The chemical standard T11 (Diafenthiuron 50% WP) exhibited the highest suppression with a 70.22% reduction over control.

Efficacy of microbial inoculants and consortia against whiteflies, *B.tabaci*

A similar trend was observed in whitefly infestation (Table 2). T5 (DBT 64 + AUDT 502+ AUDP 279) achieved the highest reduction (64.55%), followed by

Table 1. Impact of microbial inoculants and consortia against thrips, *S. dorsalis*

Treatments	PTC	30 DAT	60 DAT	90 DAT	Mean	Reduction (%)
T1	4.45 (2.11)	3.04 (1.74)	2.84 (1.69)	2.64 (1.62)	2.84 (1.69)	37.95
T2	4.55 (2.13)	3.13 (1.77)	2.93 (1.71)	2.73 (1.65)	2.93 (1.71)	35.98
T3	4.64 (2.15)	2.99 (1.73)	2.79 (1.67)	2.59 (1.61)	2.79 (1.67)	39.04
T4	4.73 (2.17)	3.08 (1.75)	2.88 (1.70)	2.68 (1.64)	2.88 (1.70)	37.07
T5	4.09 (2.02)	2.17 (1.47)	1.97 (1.40)	1.77 (1.33)	1.97 (1.40)	56.96
T6	4.18 (2.04)	2.21 (1.49)	2.01 (1.42)	1.81 (1.35)	2.01 (1.42)	56.08
T7	4.27 (2.07)	2.08 (1.44)	1.88 (1.37)	1.68 (1.30)	1.88 (1.37)	58.92
T8	4.36 (2.09)	2.12 (1.46)	1.92 (1.39)	1.72 (1.31)	1.92 (1.39)	58.05
T9	4.91 (2.22)	3.40 (1.84)	3.20 (1.79)	3.00 (1.73)	3.20 (1.79)	30.08
T10	4.82 (2.20)	3.17 (1.78)	2.97 (1.72)	2.77 (1.66)	2.97 (1.72)	35.11
T11	4.00 (2.00)	1.02 (1.01)	0.82 (0.91)	0.62 (0.79)	0.82 (0.91)	82.08
T12	4.76 (2.19)	4.43 (2.10)	4.51 (2.12)	4.79 (2.19)	4.58 (2.14)	-
SEm±	0.03	0.04	0.05	0.06	0.05	-
CD	NS	0.12	0.14	0.16	0.15	-

***NS- Non-significant, PTC- Pre - treatment count**

Table 2. Impact of microbial inoculants and consortia against whiteflies, *B. tabaci*

Treatments	PTC	30 DAT	60 DAT	90 DAT	Mean	Reduction (%)
T1	3.51 (1.87)	3.11 (1.76)	3.48 (1.87)	3.74 (1.93)	3.44 (1.86)	39.87
T2	3.62 (1.90)	3.20 (1.79)	3.53 (1.88)	3.81 (1.95)	3.51 (1.87)	38.65
T3	3.48 (1.87)	3.35 (1.83)	3.63 (1.91)	3.92 (1.98)	3.63 (1.91)	36.55
T4	3.79 (1.95)	3.42 (1.85)	3.70 (1.92)	3.99 (2.00)	3.70 (1.92)	35.33
T5	3.40 (1.84)	2.21 (1.49)	2.03 (1.42)	1.85 (1.36)	2.03 (1.42)	64.55
T6	3.72 (1.93)	2.34 (1.53)	2.17 (1.47)	1.97 (1.40)	2.16 (1.47)	62.28
T7	3.36 (1.83)	2.08 (1.44)	1.91 (1.38)	1.72 (1.31)	1.90 (1.38)	66.76
T8	3.89 (1.97)	2.44 (1.56)	2.25 (1.50)	2.06 (1.44)	2.25 (1.50)	60.71
T9	3.55 (1.88)	3.71 (1.93)	3.83 (1.96)	3.98 (1.99)	3.84 (1.96)	32.95
T10	3.67 (1.92)	3.66 (1.91)	3.58 (1.89)	3.77 (1.94)	3.67 (1.92)	35.91
T11	3.45 (1.86)	1.92 (1.39)	1.76 (1.33)	1.59 (1.26)	1.76 (1.33)	69.32
T12	3.69 (1.92)	4.83 (2.20)	5.83 (2.41)	6.52 (2.55)	5.73 (2.39)	-
SEm±	0.03	0.04	0.05	0.06	0.05	-
CD	NS	0.12	0.14	0.16	0.15	-

***NS- Non-significant, PTC- Pre - treatment count**

T6 (61.36%), T7 (60.00%), and T8 (58.18%). Individual microbial treatments, T1 to T4, recorded moderate efficacy ranging from 35.33% to 39.87%. The chemical control T11 showed the greatest reduction in whitefly population (72.73%), outperforming all microbial treatments.

Efficacy of microbial inoculants and consortia against aphids, *A. gossypii*

The aphid population was significantly reduced in microbial consortia treatments (Table 3). T5 (DBT 64 + AUDT 502+ AUDP 279) led to the highest suppression (48.78%), followed by T6 (46.34%), T7 (43.90%), and T8 (41.46%). Individual actinobacterial and pseudomonas treatments—T1 (19.51%), T2 (17.07%), T3 (14.63%), and T4 (12.20%)—showed lower efficacy. The insecticide treatment T11 once again recorded the maximum reduction (65.85%) among all treatments.

Among all microbial treatments, T5 consistently exhibited superior efficacy across thrips, whiteflies, and aphids, indicating broad-spectrum pest suppression. This effectiveness likely stems from synergistic interactions among microbes that amplify induced systemic resistance (ISR) mechanisms in the host plant. Actinobacteria are known to activate jasmonic acid and ethylene signaling pathways, resulting in increased accumulation of defense enzymes like peroxidases, polyphenol oxidases, and pathogenesis-related proteins (Conn et al., 2008). Similarly, arbuscular mycorrhizal fungi (AMF) enhance nutrient uptake, promote plant vigor, and modulate hormonal pathways, all of which contribute to improved host resistance.These findings align with those of Goudjal et al. (2014), who demonstrated the ability of *Streptomyces* spp. to suppress *Rhizoctonia solani* through hydrolytic enzyme production and systemic resistance induction. Plant growth-promoting rhizobacteria (PGPR) such as *Pseudomonas* spp. used in consortial treatments (T7 and T8), produce phenazine, hydrogen cyanide, siderophores, and β-1,3-glucanase—all of which are associated with ISR activation and insect suppression in chilli (Naik et al., 2011).The utility of these microbial consortia is further validated by field-based IPM studies, where *Pseudomonas*spp. application significantly reduced the incidence of sucking pests and lowered insecticide usage by over 30%, while increasing yield by 28% compared to non-IPM plots (Naik et al., 2011). Similarly, bio-intensive IPM modules combining *L.lecanii*, Azadirachtin, neem cake, and trap/barrier crops provided consistent control of thrips and mites (1.88/leaf and 1.16/leaf, respectively), while conserving natural enemies such as spiders and coccinellids (Kurbett et al., 2018). Although chemical-intensive modules offered the highest pest reduction and yield (12.36 q/ha), the bio-intensive systems delivered greater ecological balance. While the synthetic insecticide Diafenthiuron remained the most effective standalone treatment across all pests,

Table 3. Impact of microbial inoculants and consortia against aphids, *A. gossyphii*

Treatments	PTC	30 DAT	60 DAT	90 DAT	Mean	Reduction (%)
T1	3.40 (1.84)	3.00 (1.73)	3.31 (1.82)	3.60 (1.90)	3.29 (1.81)	19.51
T2	3.50 (1.87)	3.09 (1.76)	3.39 (1.84)	3.69 (1.92)	3.39 (1.84)	17.07
T3	3.61 (1.90)	3.18 (1.78)	3.51 (1.87)	3.80 (1.95)	3.50 (1.87)	14.63
T4	3.70 (1.92)	3.29 (1.81)	3.61 (1.90)	3.90 (1.97)	3.62 (1.90)	12.20
T5	3.30 (1.82)	2.30 (1.52)	2.10 (1.45)	1.90 (1.38)	2.10 (1.45)	48.78
T6	3.80 (1.95)	2.41 (1.55)	2.20 (1.48)	2.00 (1.41)	2.20 (1.48)	46.34
T7	3.20 (1.79)	2.11 (1.45)	1.90 (1.38)	1.71 (1.31)	1.89 (1.37)	53.66
T8	3.91 (1.98)	2.51 (1.58)	2.30 (1.52)	2.08 (1.44)	2.31 (1.52)	43.90
T9	3.40 (1.84)	3.40 (1.84)	3.60 (1.90)	3.81 (1.95)	3.60 (1.90)	12.20
T10	3.61 (1.90)	3.51 (1.87)	3.30 (1.82)	3.58 (1.89)	3.46 (1.86)	15.37
T11	3.29 (1.81)	1.90 (1.38)	1.70 (1.30)	1.51 (1.23)	1.69 (1.30)	58.54
T12	3.50 (1.87)	3.80 (1.95)	4.10 (2.02)	4.39 (2.10)	4.10 (2.02)	-
SEm±	0.03	0.04	0.05	0.06	0.05	-
CD	NS	0.12	0.14	0.16	0.15	-

***NS- Non-significant, PTC- Pre - treatment count**

microbial consortia provide long-term advantages. They reduce reliance on chemicals, maintain beneficial arthropods, and improve soil health—features critical for sustainable pest management in crops like chilli where residue concerns are high.Among the biocontrol agents, *L. lecanii* has shown high efficacy under controlled environments. Abdulle et al. (2020) reported up to 93% mortality of *B.tabaci* in vitro within 7 days using *L. lecanii* strain V-3. Likewise, Wade et al. (2020) demonstrated aphid suppression in tomato using *L. lecanii* at 5 mL/L, achieving efficacy comparable to chemical insecticides. Although its performance in the field is influenced by environmental factors like humidity and temperature, these studies highlight its biopesticidal potential. In contrast, ISR-inducing microbes offer consistent performance across varied environmental conditions, providing a more stable approach to pest suppression.Overall, the consortia involving actinobacteria, *Pseudomonas* spp.and AMF not only proved effective against chilli sucking pests but also offer a promising alternative to chemical pesticides. Their integration into eco-friendly IPM frameworks can support sustainable pest management strategies.

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MS Received: 17 May 2025
MS Acceptance: 05 June 2025

Pest Management in Horticultural Ecosystems
Vol. 31, No.1 pp 53-59 (2025)
DOI Number : 10.5958/0974-4541.2025.00016.8

Evaluation of bio-pesticides and chemicals against brinjal shoot and fruit borer, *Leucinodes orbonalis* Guenee

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ABSTRACT: The field experiment was conducted at K.N.K, College of Horticulture, Mandsaur (M.P.) to study the efficacy of certain bio-pesticides and chemicals against brinjal shoot and fruit bore, *Leucinodes orbonalis* Guenee in Mandsaur District of Madhya Pradesh during *rabi* season of 2022-23 and 2023-24. Emamectin benzoate 3% + thiamethoxam 12% @ 150 g ha^{-1} was the most effective in recording the minimum fruit infestation of (3.87%) and found at par with thiamethoxam 12.6% + lambda cyhalothrin 9.5% @ 125 ml ha^{-1}(5.81%) followed by Spinosad 45% SC @185 ml ha^{-1}(9.57%), Neem extract 3% @ 2500 ml ha^{-1}(10.06%), *Brahmastra* (Natural) @ 25 L ha-^{1} (10.95%), *Neemastra* (Natural) @ 25 L ha-^{1} (11.28%), *Agniastra* (Natural) @ 12.5 L ha-^{1} (12.38 %), *Beauveria bassiana* 1.15% WP @ 2500 g ha^{-1}(12.50%) and *Metarhizium anisopliae* 1.15% WP @ 2500 ml ha^{-1}(13.25%). The maximum fruit yield (257.00 q/ha), highest net profit (Rs. 372732.4 ha^{-1}) and highest cost benefit ratio (1:5.80) was recorded with the application of emamectin benzoate 3% + thiamethoxam 12%. Other treatments gave yield ranging from 202.80-85.57 q/ha with comparatively economics.

Keywords: Brinjal, Shoot and fruit borer, *Leucinodes orbonalis*, bio-pesticides, insecticides, yield, efficacy

INTRODUCTION

The eggplant or brinjal (*Solanum melongena* Linnaeus), is an important vegetable crop of India. Fruits of the brinjal plant are a good source of vitamins and minerals (Tripura *et al.,* 2017). Calcium, phosphorus, iron, and vitamins, are all present in very substantial amounts in its fruits. Because the pulp and seeds of brinjal contain more polyunsaturated fatty acids, it has the ability to lower cholesterol (Anonymous, 2024-25). It has become an important economic source for farmers and field laborers. It is also used as a raw material in pickle making, an excellent remedy for curing diabetes, good appetizer, good aphrodisiac, cardio tonic, laxative, and reliever of inflammation (Shridhara, 2019). Brinjal is grown extensively in India, in 6.81 lakh hectares, 128.10 lakh tones production and 18,800 kg/hectare (18.81 tones/ha) productivity. (Anonymous, 2023-24) [b]. In Madhya Pradesh total area under brinjal cultivation is 0.71 lakh hectares with production of 15.15 lakh tones and productivity of 21.33 tones (Anonymous, 2024).

Brinjal shoot and fruit borer, *Leucinodes orbonalis* Guenee. is considered to be the most dangerous and destructive pest, resulting in significant losses in brinjal production, causes crop losses ranging from 85 to 90 percent in different regions of the nation (Jangid and Kumar 2024). The recent trend to manage insects-pests is to apply novel insecticides with the combination of other group of insecticides but, due to knock down effect, synthetic insecticides are preferred. Further, an option is to use native plant products and organic components to avoid the residue problem. Additionally, it was discovered that diluted *Agniastra* 3% and *Bhramhastra* 3% exhibited promising organic treatments (Rathod *et al.,* 2016).The national interest is to produce residue free vegetables and other products. This functioned as the background for the present investigation, which looked at how well different organic and bio-rational pesticides, worked against fruit and shoots borer in the field as compared to combination chemical insecticides.

MATERIALS AND METHODS

The experiment was carried out during *rabi*, 2022-23 & 2023-24 on brinjal at Experimental farm of K.N.K, College of Horticulture, Mandsaur (M.P.). Seedlings of variety KSP-1229 rajat, were transplanted with at 60 x 45cm spacing in plot size of 3 x 3m. Randomized block design (RBD) was followed with treatments T_1-*Neemastra* (Natural) @ 25 L ha^{-1}, T_2-*Brahmastra* (Natural) @ 25 L ha^{-1}, T_3-*Agniastra* (Natural) @ 12.5

L ha^{-1}, T_4-*Metarhizium anisopliae* 1.15% WP @ 2500 ml ha^{-1}, T_5-Spinosad 45% SC @ 185 ml ha^{-1}, T_6-Neem extract 3% @ 2500 ml ha^{-1}, T_7-*Beauveria bassiana* 1.15% WP @ 2500 g ha^{-1}, T_8- Emamectin benzoate 3% + thiamethoxam 12% @ 150 g ha^{-1}, T_9-Thiamethoxam 12.6% + lambda cyhalothrin 9.5% @ 125 ml ha^{-1}. Observations were recorded on the fruit infestation terms of number of damaged fruits computed to pre-treatment observation and 3,7,10 days after each spray based on total no. of fruits and damaged fruit. Marketable fruit yield was also recorded. Data were subjected to ANOVA after transformation.

$$\text{Per cent fruit infestation} = \frac{\text{Total no. of infested fruit}}{\text{Total no. of fruits}} \times 100$$

Neemastra preparation

Crushed 5 kg neem leaves in water, added 5 l cow urine and 2 kg cow dung, fermented for 24 hours with intermittent stirring, filter squeeze the extract around five liter and applied @ 25.0 liter per hectare.

Brahmastra preparation

Crushed 3 kg neem leaves in 10 l of cow urine. Crushed 2 kg custard apple leaf, 2 kg papaya leaf, 2 kg pomegranate leaves, 2 kg guava leaves in water. Mixed and boiled up to 5 times at some interval till it become half. Kept it for 24 h, then filtered and squeezed the extract. This can be stored in bottles for 6 months and applied @ 25.0 liter per hectare.

Agniastra preparation

Crushed 1 Kg Ipomoea leaves, 500 g chili, 500 g garlic and 5 kg neem leaves in 10 lit of cow urine. Mixed it well clockwise and closed it with a lid. Boiled the liquid for half of the quantity and then allowed it to cool and applied @ 12.5 l per hectare.

RESULTS AND DISCUSSION

During two years study and also in pooled analysis, the treatment of insecticidal combination played significant role in reducing the infestation on brinjal fruits. Although all the treatments exhibited significant effect over untreated check in all the intervals of observation during overall study 2023-24 (Table 2) and pooled (Table 3). In first year (Table-1), emamectin benzoate 3% + thiamethoxam 12% @ 150 g ha^{-1} was gave highest reduction over control (91.13%) followed by thiamethoxam 12.6% + lambda cyhalothrin 9.5% @ 125 ml ha^{-1}(85.45%), Spinosad 45% SC @185 ml ha^{-1}(75.35%), Neem extract 3% @ 2500 ml ha^{-1}(73.92%), *Brahmastra* (Natural) @ 25 L ha-^{1} (70.74%), *Neemastra* (Natural) @ 25 L ha-^{1} (68.10%), *Beauveria bassiana* 1.15% WP @ 2500 g ha^{-1}(65.67%) and *Agniastra* (Natural) @ 12.5 L ha-^{1} (64.88%), *Metarhizium anisopliae* 1.15% WP @ 2500 ml ha^{-1}(63.88%). During second year (Table-2), emamectin benzoate 3% + thiamethoxam 12% @ 150 g ha^{-1} (90.03%) again recorded highest reduction followed by Thiamethoxam 12.6% + lambda cyhalothrin 9.5% @ 125 ml ha^{-1}(86.20%), Spinosad 45% SC @185 ml ha^{-1}(77.91%), Neem extract 3% @ 2500 ml ha^{-1}(76.91%), *Neemastra* (Natural) @ 25 L ha-^{1} (76.52 per cent), *Brahmastra* (Natural) @ 25 L ha-^{1} (75.66%), *Agniastra* (Natural) @ 12.5 L ha-^{1} (74.36%), *Beauveria bassiana* 1.15% WP @ 2500 g ha^{-1}(73.06%) and *Metarhizium anisopliae* 1.15% WP @ 2500 ml ha^{-1} (71.22%). Further same trend of infestation reduction in fruit and shoot borer was noted in pooled analysis (Table 3) as it was maximum (90.57%) in emamectin benzoate 3% + thiamethoxam 12% @ 150 g ha^{-1} followed by thiamethoxam 12.6% + lambda cyhalothrin 9.5% @ 125 ml ha^{-1} (85.84%), Spinosad 45% SC @ 185 ml ha^{-1} (76.68%), Neem extract 3% @ 2500 ml ha^{-1} (75.49%), *Brahmastra* (Natural) @ 25 L ha^{-1}(73.32%), *Neemastra* (Natural) @ 25 L ha^{-1}(72.52%), *Agniastra* (Natural) @ 12.5 L ha^{-1} (69.84%), *Beauveria bassiana* 1.15% WP @ 2500 g ha^{-1} (69.54%) and M*etarhizium anisopliae* 1.15% WP @ 2500 ml ha^{-1} (67.72%). The present observations on the effectiveness of combination of insecticides are in partial conformity with those of Mollah (2025) in brinjal against *L. orbonalis* found lowest fruit infestation with Emamectin benzoate 1% + azadirachtin 1%. Rahman *et al.* (2019) reported that emamectin Benzoate +Abamectin @ 0.50 g/L recorded the lowest fruit infestation. Another study by Anand *et al.* (2014) reported that emamectin benzoate, in combination with azadirachtin-based Neem Baan, provided the lowest fruit infestation by both number and weight basis. Furthermore, the past results of the experiment by Kumari *et al.* (2023); Sood *et al.* (2023); Siddhartha *et al.* (2025) proved that the use of emamectin Benzoate protected brinjal fruit significantly from BSFB infestation. Spinosad 45 SC and emamectin benzoate 5 SG, 0.002% was found to be equally efficacious for lowering the infestation of BSFB reported by Warghat *et al.* (2020) and (Jangid and Kumar 2024).

Likewise, in a separate study conducted by Ullah *et al*. (2021), it was reported that Neem oil 5% had the lowest fruits infestation, the most flowers per plant and the maximum brinjal yield. Singh *et al.* (2025) noted

Table 1. Efficacy of organic and bio-rational insecticide against brinjal shoot and fruit borer during *rabi*, 2022-23

S. No.	Treatment	Dosage (G or ml/ ha or %)	Fruit damage by shoot and fruit borer							Overall Reduction (%)
				After first spray			After second spray			
			1 DBS	3 DAS	7 DAS	10 DAS	3 DAS	7 DAS	10 DAS	
T_1	*Neemastra* (Natural)	25 L	23.81 (29.54)	17.83 (25.32)	19.62 (26.64)	20.47 (27.20)	11.63 (20.25)	11.29 (19.98)	12.45 (21.01)	**68.10**
T_2	*Brahmastra* (Natural)	25 L	22.95 (28.96)	16.29 (24.00)	18.42 (25.63)	19.05 (26.00)	11.10 (19.83)	10.73 (19.53)	11.42 (20.13)	**70.74**
T_3	*Agniastra* (Natural)	12.5 L	24.17 (29.78)	18.60 (25.88)	21.01 (27.53)	25.58 (30.68)	12.68 (21.20)	12.40 (20.98)	13.71 (22.08)	**64.88**
T_4	*Metarhizium anisopliae* 1.15% WP	2500 ml	23.95 (29.63)	19.35 (26.41)	24.06 (29.62)	26.63 (31.27)	13.24 (21.70)	12.84 (21.39)	14.10 (22.44)	**63.88**
T_5	Spinosad 45% SC	185 ml	24.10 (29.73)	13.85 (22.25)	16.07 (23.98)	16.24 (24.08)	9.32 (18.26)	9.24 (18.18)	9.62 (18.55)	**75.35**
T_6	Neem extract 3%	2500 ml	23.97 (29.65)	15.14 (23.18)	16.93 (24.65)	17.30 (24.88)	10.72 (19.49)	9.85 (18.67)	10.18 (18.97)	**73.92**
T_7	*Beauveria bassiana* 1.15% WP	2500 g	24.32 (29.87)	19.76 (26.73)	22.54 (28.65)	25.33 (30.47)	12.42 (20.99)	12.19 (20.79)	13.40 (21.82)	**65.67**
T_8	Emamectin benzoate 3% + Thiamethoxam 12%	150 g	23.68 (29.46)	6.50 (15.28)	7.04 (15.89)	7.89 (16.77)	3.25 (10.96)	2.85 (10.47)	3.46 (11.35)	**91.13**
T_9	Thiamethoxam 12.6% +Lambda cyhalothrin 9.5%	125 ml	23.38 (29.23)	8.57 (17.43)	9.07 (17.93)	9.66 (18.56)	5.28 (13.92)	4.70 (13.05)	5.68 (14.20)	**85.45**
T_{10}	Untreated	-	23.93 (29.61)	25.76 (30.82)	28.33 (32.47)	31.02 (34.13)	34.55 (36.29)	36.89 (37.69)	39.04 (38.94)	**-**
	S Em±	-	0.50	1.37	1.48	1.58	1.27	1.19	1.35	-
	CV %	-	NS	10.03	10.11	10.34	10.86	10.31	11.16	-
	CD at 5 %	-	NS	4.08	4.39	4.68	3.78	3.55	4.01	-

The values in parentheses are angular transformed values, DBS= Days before spray, DAS = Days after spray

that modified *Agniastra* (MAA) at 7.5 L/ha, significantly lowered the fruit damage (10.15%) due to shoot and fruit borer followed by modified Brahmastra (MBA) at 10 L/ ha. However, we discovered that the following treatments were quite helpful in managing BSFB. Furthermore, Akter *et al.* (2017) recorded lowest fruit infestation in the plots treated with spinosad 45 SC followed by emamectin benzoate 5 SG. Mahajan *et al.* (2020) stated that neem oil 2% @ 5ml/lit showed efficient treatments against BSFB. These findings are also in partial support to present study.

Yield

In both years, the yield of brinjal fruits (Table-4) differed significantly between different treatments. In 2022-23 and 2023-24, the yield varied between 90.02 and 268.88 q/ha and 81.13 and 245.13 q/ha, respectively. The Emamectin benzoate 3% + Thiamethoxam 12% treated plots produced the highest overall pooled yield (257.00 q/ha) which exhibited significance with Thiamethoxam 12.6% +Lambda cyhalothrin 9.5% (202.80 qt ha^{-1}), Spinosad 45% SC @185 ml ha^{-1}(192.71 qt ha^{-1}), Neem

Table 2. Efficacy of organic and bio-rational insecticide against brinjal shoot and fruit borer during *rabi*, 2023-24

S. No.	Treatment	Dosage per ha	Fruit damage by shoot and fruit borer							Overall Reduction (%)
				After first spray			After second spray			
			1 DBS	3 DAS	7 DAS	10 DAS	3 DAS	7 DAS	10 DAS	
T_1	*Neemastra* (Natural)	25 L	36.81 (35.95)	12.72 (21.27)	15.09 (23.12)	16.12 (24.01)	10.58 (19.36)	9.91 (18.69)	10.11 (18.89)	**76.52**
T_2	*Brahmastra* (Natural)	25 L	35.95 (37.14)	13.24 (21.69)	15.56 (23.57)	16.50 (24.20)	10.80 (19.55)	10.21 (18.98)	10.48 (19.25)	**75.66**
T_3	*Agniastra* (Natural)	12.5 L	37.17 (37.86)	15.44 (23.43)	16.32 (24.13)	16.91 (24.63)	11.21 (19.88)	10.67 (19.40)	11.04 (19.76)	**74.36**
T_4	*Metarhizium anisopliae* 1.15% WP	2500 ml	36.95 (37.73)	17.10 (24.74)	17.73 (25.24)	19.67 (26.62)	12.36 (20.95)	11.83 (20.47)	12.39 (20.93)	**71.22**
T_5	Spinosad 45% SC	185 ml	37.10 (37.82)	11.45 (20.20)	12.53 (21.11)	12.94 (21.43)	9.04 (17.98)	8.71 (17.64)	9.51 (18.43)	**77.91**
T_6	Neem extract 3%	2500 ml	36.97 (37.74)	12.05 (20.73)	13.12 (21.60)	14.01 (22.33)	10.39 (19.14)	9.72 (18.55)	9.94 (18.76)	**76.91**
T_7	*Beauveria bassiana* 1.15% WP	2500 g	37.32 (37.95)	16.09 (23.98)	16.87 (24.57)	17.85 (25.33)	11.62 (20.25)	11.13 (19.78)	11.60 (20.21)	**73.06**
T_8	Emamectin benzoate 3% + Thiamethoxam 12%	150 g	36.68 (37.57)	5.67 (14.15)	6.11 (14.63)	7.29 (15.97)	4.36 (12.55)	3.97 (12.14)	4.29 (12.50)	**90.03**
T_9	Thiamethoxam 12.6% +Lambda cyhalothrin 9.5%	125 ml	35.38 (36.78)	6.87 (15.62)	7.52 (16.08)	8.40 (17.08)	5.37 (13.95)	5.06 (13.47)	5.94 (14.44)	**86.20**
T_{10}	Untreated	-	36.93 (37.72)	37.09 (37.80)	39.06 (38.96)	41.39 (40.32)	41.83 (40.59)	42.35 (40.89)	43.06 (41.30)	**0.00**
	S Em±	-	0.58	1.36	1.45	1.46	1.31	1.25	1.31	
	CV %	-	NS	10.52	10.78	10.46	11.14	10.84	11.12	
	CD at 5 %	-	NS	4.04	4.31	4.34	3.90	3.72	3.90	

The values in parentheses are angular transformed values, DBS= Days before spray, DAS = Days after spray

extract 3% @ 2500 ml ha^{-1}(184.82qt ha^{-1}), *Brahmastra* (Natural) @ 25 L ha^{-1}(166.87qt ha^{-1}), *Neemastra* (Natural) @ 25 L ha^{-1}(162.31qt ha^{-1}), *Agniastra* (Natural) @ 12.5 L ha^{-1}(152.52qt ha^{-1}) followed by *Beauveria bassiana* 1.15% WP @ 2500 g ha^{-1}(138.98qt ha^{-1}) and *Metarhizium anisopliae* 1.15% WP @ 2500 ml ha^{-1}(120.62qt ha^{-1}). The pooled lowest fruit yield 85.57 quintal per hectare registered in untreated check. The findings of previous researchers are in partial support as Kumari *et al.* (2023) reported the highest brinjal fruit yield obtained with treatment Emamectin benzoate 5 SG. A slight similar result was noted with Sood *et al.* (2023) reported maximum fruit yield in emamectin benzoate (51.67 q/ ha) which was at par with Brahmastra (45.50 q/ ha) and *Agniastra* (41.67 q/ ha). Application of Cyclone 2.5 EC (Lambda-cyhalothrin) has significantly increased marketable yield and decreased infested fruit yield compared to untreated control as reported by Rahman *et al.* (2019).

Economics of different insecticides

Emamectin benzoate 3% + thiamethoxam 12% ha^{-1} yielded the highest net return (Rs. 372732.4 ha^{-1}) and benefit-cos ratio (5.80) (Table 4) followed by

Table 3. Efficacy of organic and bio-rational insecticide against brinjal shoot and fruit borer during *rabi*, 2022-23 and 2023-24 (Pooled)

S. No.	Treatment	Dosage (G or ml/ ha or %)	Fruit damage by shoot and fruit borer							Overall Reduction (%)
			After first spray				After second spray			
			1 DBS	3 DAS	7 DAS	10 DAS	3 DAS	7 DAS	10 DAS	
T_1	*Neemastra* (Natural)	25 L	30.31 (33.60)	15.28 (23.29)	17.35 (24.88)	18.29 (25.61)	11.10 (19.80)	10.60 (19.34)	11.28 (19.95)	**72.52**
T_2	*Brahmastra* (Natural)	25 L	29.45 (33.05)	14.77 (22.85)	16.99 (24.60)	17.78 (25.10)	10.95 (19.69)	10.47 (19.25)	10.95 (19.69)	**73.32**
T_3	*Agniastra* (Natural)	12.5 L	30.67 (33.82)	17.02 (24.66)	18.67 (25.83)	21.24 (27.66)	11.94 (20.54)	11.54 (20.19)	12.38 (20.92)	**69.84**
T_4	*Metarhizium anisopliae* 1.15% WP	2500 ml	30.45 (33.68)	18.23 (25.57)	20.90 (27.43)	23.15 (28.95)	12.80 (21.33)	12.34 (20.93)	13.25 (21.68)	**67.72**
T_5	Spinosad 45% SC	185 ml	30.60 (33.78)	12.65 (21.23)	14.30 (22.54)	14.59 (22.75)	9.18 (18.12)	8.97 (17.91)	9.57 (18.49)	**76.68**
T_6	Neem extract 3%	2500 ml	30.47 (33.69)	13.60 (21.95)	15.03 (23.12)	15.66 (23.61)	10.55 (19.31)	9.79 (18.61)	10.06 (18.87)	**75.49**
T_7	*Beauveria bassiana* 1.15% WP	2500 g	30.82 (33.91)	17.93 (25.35)	19.70 (26.61)	21.59 (27.90)	12.02 (20.62)	11.66 (20.28)	12.50 (21.01)	**69.54**
T_8	Emamectin benzoate 3% + Thiamethoxam 12%	150 g	30.18 (33.51)	6.08 (14.72)	6.58 (15.26)	7.59 (16.37)	3.81 (11.75)	3.41 (11.31)	3.87 (11.92)	**90.57**
T_9	Thiamethoxam 12.6% +Lambda cyhalothrin 9.5%	125 ml	29.38 (33.01)	7.72 (16.52)	8.30 (17.00)	9.03 (17.37)	5.33 (13.93)	4.88 (13.26)	5.81 (14.32)	**85.84**
T_{10}	Untreated	-	30.43 (33.66)	31.43 (34.31)	33.69 (35.71)	36.20 (37.23)	38.19 (38.44)	39.62 (39.29)	41.05 (40.12)	**0.00**
	S Em±	-	0.54	1.37	1.46	1.52	1.29	1.22	1.33	
	CV %	-	NS	10.27	10.44	10.40	11.00	10.57	11.14	
	CD at 5 %	-	NS	4.06	4.35	4.51	3.84	3.63	3.95	

The values in parentheses are angular transformed values, DBS= Days before spray, DAS = Days after spray

thiamethoxam 12.6% + lambda cyhalothrin 9.5% (Rs. 280624.8 ha^{-1} and B: C 4.37). Among herbal products, *Brahmastra* (Natural) @ 25 L ha^{-1} gave net returns of Rs. 213719 ha^{-1} and B:C ratio of 3.05 and *Neemastra* (Natural) @ 25 L ha^{-1} followed with B:C ratio of 3.00). In our study Spinosad and neem pesticides were found to be efficacious after combination insecticides with the maximum BC ratio. Sahu *et al.* (2023) assessed that Emamectin benzoate 5 SG @ 200 g/ha (1:17.04) had the highest brinjal fruit yield (265.61 q/ha), the highest net profit (Rs. 63,075.78), and the highest cost-benefit ratio. Additionally, the BC ratio of brinjal fruit treated with Emamectin Benzoate was higher than that of *Brahmastra*, *Neemastra* and *Agniastra*, as shown by Tayde and Sharma (2017). Our results also concur with those of Gandla and Kumar (2022) and Yousafi *et al.* (2016) who found that Emamectin benzoate was the most cost-effective treatment for BSFB in the field, with a higher BC ratio than Spinosad and neem oil. Further, Khanal *et al.* (2021) concluded that both marketable yield and Benefit-Cost ratio of under treatment of Emamectin benzoate against brinjal fruit borer were highest followed

Table 4. Effect of insecticides on brinjal fruit yield during *rabi* 2022-23 & 2023-24 (Pooled)

S. No.	Treatment	Yield, 2022-23 (q ha^{-1})	Yield, 2023-24 (q ha^{-1})	Pooled Yield (q ha^{-1})	B:C Ratio
T_1	*Neemastra* (Natural)	164.04	160.58	162.31	3.00
T_2	*Brahmastra* (Natural)	177.62	156.11	166.87	3.05
T_3	*Agniastra* (Natural)	153.71	151.33	152.52	2.75
T_4	*Metarhizium anisopliae* 1.15% WP	114.80	126.44	120.62	2.11
T_5	Spinosad 45% SC	197.13	188.29	192.71	3.85
T_6	Neem extract 3%	191.09	178.56	184.82	3.61
T_7	*Beauveria bassiana* 1.15% WP	138.27	139.69	138.98	2.56
T_8	Emamectin benzoate 3% + Thiamethoxam 12%	268.88	245.13	257.00	5.80
T_9	Thiamethoxam 12.6% +Lambda cyhalothrin 9.5%	211.82	193.78	202.80	4.37
T_{10}	Untreated	90.02	81.13	85.57	1.32
	S Em±	18.68	16.90	18.96	
	CD at 5 %	55.49	50.22	52.86	

by Jholmal and Neem Kavach. Whereas, Jangid and Kumar 2024 proved that Spinosad 45 SC (180 q/ha, 1:9.3) was more effective among all other treatments, followed by emamectin Benzoate5 SG (155.60, 1:9.2).

Conclusion

It is clear that all the treatments were able to significantly lower the infestation of BSFB in the field. It was concluded that combination insecticides emamectin benzoate 3% + thiamethoxam 12% 150 g ha^{-1} and thiamethoxam 12.6% + lambda cyhalothrin 9.5% @ 125 ml ha^{-1} were the best among the tested bio-rational pesticides, while Spinosad and organic pesticides were equally efficacious for the management of BSFB. Fruit yield and BC ratio of emamectin benzoate 3% + thiamethoxam 12%was highest followed by thiamethoxam 12.6% + lambda cyhalothrin 9.5% @ 125 ml ha^{-1}, spinosad 45% SC @ 185 ml ha^{-1}, Neem extract 3% @ 2500 ml ha^{-1}, *Brahmastra* (Natural) @ 25 L ha-^{1}, *Neemastra* (Natural) @ 25 L ha-^{1}, *Agniastra* (Natural) @ 12.5 L ha-^{1}, *Beauveria bassiana* 1.15% WP @ 2500 g ha^{-1} and *Metarhizium anisopliae* 1.15% WP.

ACKNOWLEDGEMENTS

The authors are grateful to Dr. SB Singh, the Head of Department of Entomology, KNK College of Horticulture, Mandsaur, RVSKVV, Gwalior for providing guidance and facilities.

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MS Received: 12 May 2025
MS Acceptance: 05 June 2025

Pest Management in Horticultural Ecosystems
Vol. 31, No.1 pp 60-66 (2025)
DOI Number : 10.5958/0974-4541.2025.00018.0

Resistance profiling of *Phthorimaea absoluta* (Meyrick) from tomato fields of Belagavi, Karnataka

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ABSTRACT: South American tomato pinworm, *Phthorimaea absoluta* (Meyrick), poses a major threat to tomato production in India, with insecticide resistance becoming a key challenge for its effective management. The present study assessed the resistance status of *P. absoluta* and surveyed insecticide use patterns in tomato fields of Belagavi district, Karnataka. Field populations were collected and leaf dip bioassays were conducted using eight insecticides. Probit analysis revealed moderate resistance to chlorantraniliprole, with an LC_{50} of 60.631 ppm and a resistance ratio of 19.24 fold compared to the susceptible strain. While, lambda-cyhalothrin (LC_{50}: 56.294 ppm; RR: 7.36), profenofos (LC_{50}: 1350.221 ppm; RR: 7.35) and emamectin benzoate (LC_{50}: 46.821 ppm; RR: 6.83) showed low levels of resistance. However, cyantraniliprole (LC_{50}: 39.987 ppm; RR: 6.65), flubendiamide (LC_{50}: 32.378 ppm; RR: 4.96), spinosad (LC_{50}: 27.107 ppm; RR: 5.44) and indoxacarb (LC_{50}: 20.609 ppm; RR: 3.45) exhibited reduced susceptibility. However, wider LC_{50} – LC_{90} gaps indicated population heterogeneity and possible resistance build-up. The insecticide usage survey revealed indiscriminate use of chlorantraniliprole, adding selection pressure and cross resistance due to possible detoxifying enzymes activity.

Keywords: South American pin worm, field population, bioassay, insecticide resistance and spraying pattern

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is an economically important vegetable crop cultivated extensively across India for its nutritional value and market demand. With an annual production exceeding 20 million metric tons from more than 841,000 hectares, India ranks second in global tomato production (Anonymous, 2024). However, the productivity and profitability of tomato cultivation have come under significant threat due to the rapid spread of the South American tomato pinworm, *Phthorimaea* (*Tuta) absoluta* (Meyrick) (Lepidoptera: Gelechiidae).

Originally described from Peru in 1917, *P. absoluta* has emerged as one of the most invasive and damaging pests of tomato crops worldwide (Omandi, 2015). Its remarkable dispersal ability has facilitated its spread across Europe, North and East Africa, the Middle East and Asia since the early 2000s (Campos, 2017). The pest was first reported in India in 2014 at the Indian Institute of Horticultural Research, Bengaluru, Karnataka (Sridhar *et al.,* 2014) and has since rapidly expanded its presence to most major tomato-growing regions in the country. Several biological and behavioural traits make *P. absoluta* exceptionally difficult to manage. Its high reproductive capacity, concealed larval feeding habits, ability to infest all aerial parts of the tomato plant and oligophagous nature allow it to escape control measures and cause severe damage throughout the crop cycle (Ferracini *et al.*, 2012). Infestations can result in yield losses as high as 80–100 per cent under both greenhouse and open-field conditions, leading to significant economic losses for growers (Desneux *et al.*, 2010).

The predominant management approach for *P. absoluta* relies heavily on chemical insecticides. However, repeated and indiscriminate applications, often with limited awareness of integrated pest management (IPM) principles, have led to widespread resistance development and reduced control efficiency (Galdino *et al.*, 2011). Early evidence of insecticide resistance was reported in South America, where field populations showed reduced susceptibility to organophosphates and pyrethroids (Lietti *et al.*, 2005). Since then, resistance to multiple chemical classes, including diamides, oxadiazines and spinosyns, has been documented in several countries (Reyes *et al.*, 2011; Campos *et al.*, 2015; Melis *et al.*, 2015; Silva *et al.*, 2016; Roditakis *et al.*, 2018; Taleh *et al.*, 2021; Zhang *et al.*, 2022). In India, recent field-level observations and laboratory studies have confirmed resistance development against commonly used insecticides, with farmers frequently experiencing unexplained field failures despite repeated applications (Prasannakumar *et al.*, 2020).

However, regular monitoring of resistance through laboratory bioassays and probit analysis remains essential to quantify current susceptibility levels and detect changes over time. Bioassays provide reliable estimates of lethal concentrations and enable comparison with known susceptible baselines (Karuppaiah *et al.*, 2017), forming a scientific basis for selecting effective insecticides and designing rotation schedules. Understanding the local patterns of insecticide application is also crucial for analysing the influence of selection pressures on the development of resistance in *P. absoluta* populations. Documenting these application practices helps identify areas where misuse may be contributing to resistance, guiding recommendations for more judicious insecticide use. Together, insights into resistance levels and insecticide application patterns offer critical baseline information for developing robust, region-specific insecticide resistance management (IRM) strategies that can sustain the productivity and profitability of tomato cultivation. In this context, the present study was undertaken to assess the resistance status of *P. absoluta* and document insecticide use practices in tomato fields of Belagavi district, Karnataka, India to support informed decision making and promote sustainable pest management in the region.

MATERIALS AND METHODS

Field collection and rearing of *P. absoluta* population

The *P. absoluta* populations used in this study were sourced from tomato fields of Tigadi village (15.806˚ N, 74.722˚ E) from Belagavi district of Karnataka state during September 2023. Independent samples of leaves and fruits of tomatoes with *P. absoluta* larvae were collected. Approximately 1000 to 1200 larvae from five different tomato fields spanning 10 km^2 were collected and brought to the Toxicology laboratory, Department of Entomology, College of Agriculture, University of Agricultural Sciences, Dharwad, Karnataka India. Larvae collected from field were reared separately in rearing cages with insect free tomato plants under controlled laboratory conditions (25 ± 2 °C, 75 ± 5% relative humidity and 12 h of light and 12 h of darkness photoperiod) up to adults. After adult emergence, 10 per cent honey solution with Vit E was provided for enhancement of reproduction efficiency and fresh tomato plant parts were provided for oviposition. Here, second instar larvae from the F_1 progeny were selected and employed for the bioassays to evaluate their response to insecticidal treatments.

The susceptible (SUS) *P. absoluta* population was developed using the larval population collected from unsprayed tomato fields from Belagavi district, Karnataka, India, during August 2023. The population was separately maintained in a controlled laboratory room following the steps and conditions described above without exposure to any insecticides up to 25 generations.

Survey for spraying pattern

A field survey was conducted alongside the collection of *P. absoluta* populations in Belagavi district during the 2023 cropping season. Farmers were asked about the

Table 1. Details of insecticides used in this study

Tr. No.	Treatment details	IRAC Groups	Trade Name	Manufacturers
T_1	Chlorantraniliprole 18.5 SC	28 / Diamide	Coragen	Du-Pont India, Ltd., Gurgaon, Haryana.
T_2	Cyantraniliprole 10.25 SC	28 / Diamide	Benallia	Du-Pont India, Ltd., Gurgaon, Haryana.
T_3	Flubendiamide 480 SC	28 / Diamide	Fame	Bayer Crop Science Ltd., Thane, Maharashtra
T_4	Indoxacarb 14.5 SC	22A / Oxadiazine	Advaunt	Kalyani Industries, Mumbai, Maharashtra.
T_5	Emamectin benzoate 5 SG	6 / Avermectins	Proclaim	Syngenta India Pvt. Ltd., Pune, Maharashtra.
T_6	Lambda-cyhalothrin 5 EC	3A / Synthetic Pyrethroid	Karate	Syngenta India Pvt. Ltd., Pune, Maharashtra.
T_7	Spinosad 45 SC	5 / Spinosyns	Badge	UPL Limited, Bengaluru, Karnataka.
T_8	Profenofos 50 EC	1B / Organophosphate	Curacron	Syngenta India Pvt. Ltd., Pune, Maharashtra
T_9	Control	-	-	

types of insecticides used and the total number of sprays applied during the tomato crop cycle. This information was used to assess spraying trends and possible selection pressure on local populations.

Bioassay

Bioassay was carried out using eight selected insecticides as furnished in Table 1., which are recommended for *P. absoluta* management and frequently used by tomato growers. Procedure of IRAC test method No. 022 was employed for bioassay to assess the level of toxicity to *P. absoluta* using leaf dip method. Prior to the finalization of five concentrations of each insecticide (in double distilled water) for bioassay, pilot study was made independently for each insecticide (commercial grade formulations) limiting mortality >20 to <80 per cent. Pest and disease free tomato seedlings were raised in the Department of Entomology, College of Agriculture, UAS, Dharwad. Uniform sized 30 days old seedlings leaves were dipped in different concentrations of insecticide solution separately, air dried and placed individually in labeled petri dishes lined with a wetted cotton layer and filter paper. Here, thirty second instar larvae were used for different concentration of each insecticide separately and replicated four times to assess the mortality at 24 h to 72 h. Moribund larvae despite co-ordinated prodding were considered as dead. Similarly a control was placed for every set of bioassay by dipping the leaf in double distilled water.

Statistical analysis

Mortality obtained from leaf dip bioassay was corrected using Abbott's formula (Abbott, 1925). The LC_{50} values were calculated by Probit analysis using Polo Plus 2.0 LeOra software (LeOra Software LLC, Parma, USA). Resistance ratios (RRs) were calculated by dividing the LC_{50} value of respective insecticide and LC_{50} value of the susceptible strain of *P. absoluta*. According to the RR value obtained, the tested insect populations were categorized as susceptible (<3.0), decreased susceptible (3.1–5.0), low resistance (5.1–10.0), moderate resistance (10.1–40.0), high resistance (40.1–160.0) and very high resistance (>160.0) (Jin *et al.,* 2016).

RESULTS AND DISCUSSION

Insecticides spraying pattern for management of *P. absoluta* in Belgavi location fields is given in Table 2. Use of chlorantraniliprole as single molecule and in combination with others was found to be highest in surveyed area. Furthermore, synthetic pyrethroids also having higher usage across area. However, 8 to 12 insecticidal sprays were operated during complete season of tomato cycle.

Relative toxicity results (Table 3.) revealed that Belgavi location field populations showed decreased susceptibility towards all the eight insecticides. Field populations showed highest resistance for chlorantraniliprole with LC_{50} value 60.631 ppm as compared to 3.152 ppm value for susceptible population with 19.24-fold resistance (Fig. 1). Next in line, lambda-cyhalothrin followed by profenofos showed 56.294 ppm and 1350.221 ppm LC_{50} values, respectively for field population with 7.36 and 7.35-fold resistance ratio, respectively. Lowest resistance development was showcased in indoxacarb treated field collected insects with 3.45-fold resistance ratio trailed by spinosad (RR 5.44-fold) with LC_{50} 27.107 ppm. Among remaining insecticides, decreasing resistance order was observed as emamectin benzoate (LC_{50} 46.821 ppm) > cyantraniliprole (LC_{50} 39.987 ppm) > flubendiamide (LC_{50} 33.378 ppm) with resistance ratio 6.83-fold, 6.65-fold and 4.96-fond,

Table 2. Usage pattern of insecticides for management of *P. absoluta* in Belgavi, Karnataka

S. No.	Technical Name	Recommended dose (ml/L)	Farmers applied dose (ml/L)	No. of sprays / season
1	Chlorantraniliprole 18.5 SC	0.30	0.50	2-3
2	Chlorantraniliprole 8.8% + Thiamethoxam 17.5% SC	0.20	0.50	1
3	Imidacloprid 17.8 5 SL	0.30	0.50	1-2
4	Chlorantraniliprole 10% + Lambda-cyhalothrin 5% ZC	0.40	0.50	2-3
5	Fipronil 40% + Imidacloprid 40% WG	0.30	0.50	1
6	Unknown	-	5.00	1-2

respectively. Overall, the goodness-of-fit χ^2 statistics for all tested populations were consistently lower than the tabulated critical values, indicating an adequate probit model fit and strengthening the confidence in the derived toxicity estimates. Additionally, the substantial disparities in LC_{50} and LC_{90} metrics across different field populations highlight the likely coexistence of resistant individuals within these groups, reaffirming the heterogeneous nature of resistance development.

Assessment of field-evolved resistance indicated the development of moderate resistance in the population for chlorantraniliprole, whereas lambda-cyhalothrin, profenofos, and emamectin benzoate showed low levels of resistance, and the remaining insecticides exhibited reduced susceptibility. The frequent and repeated use of chlorantraniliprole without proper rotation with insecticides of different modes of action appears to have exerted strong selection pressure on *P. absoluta* populations. This is consistent with the findings of Silva *et al.,* (2019), who demonstrated that continuous selection of a susceptible *P. absoluta* population with chlorantraniliprole for over 15 generations resulted in a resistance increase of 10,76,955-fold compared with the initial level, clearly showing how selection pressure can accelerate resistance development. In addition, the role of detoxification enzymes cannot be overlooked, as these enzymes are not specific to a single insecticide group but act on structural similarities among molecules, thereby increasing the chances of cross-resistance. Future studies are needed to quantify the contribution of detoxifying enzymes in elevating resistance levels.

However, there is no any resistance level assessment study previously on *P. absoluta* from Belagavi location of Karnataka. Hence, present study results are compared with other field locations from South India. Mohan *et al.* (2025) revealed that Coimbatore (Tamil Nadu) and Kolar (Karnataka) showed LC_{50} values as 28.38 ppm and 45.66 ppm, respectively for flubendiamide. Whereas, chlorantraniliprole showed 61.73 ppm and 66.50 ppm LC_{50} values for Bengaluru and Kolar location field population, respectively. Similarly, Coimbatore and Dharmapuri from Tamil Nadu showed LC_{50} value as 27.87 ppm and 33.82 ppm, respectively. These results are very closely aligned with present study showing similar trend in resistance development. Prasannakumar *et al.* (2021) conducted bioassay to assess resistance levels from 6 locations of South India and found that Anantapur field location from Andhra Pradesh showed LC_{50} values as 33.216 ppm for indoxacarb, 32.343 ppm for flubendiamide, 29.270 ppm for emamectin benzoate and 29.495 ppm for cyantraniliprole, which were highest among all locations. However, other locations showcased low resistance level indicating less selection pressure. Certainly, few studies exhibited very less resistance among

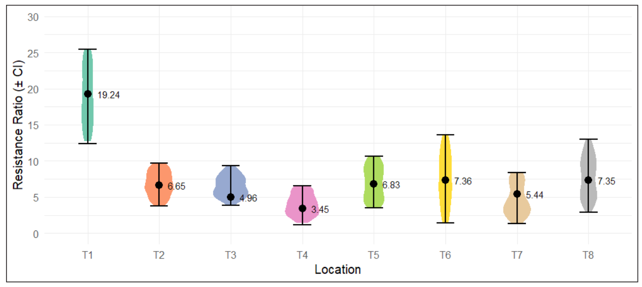

Fig. 1. Resistance ratios for different insecticides in field collected *P. absoluta* population

South Indian field population denoting the correct spraying pattern and negligible selection pressure. Study conducted in 2017-18 from 5 field collected *P. absoluta* population from Tamilnadu state emphasized less than 2-fold resistance for Chlorantraniliprole, Chlorpyriphos, Flubendiamide, Imidacloprid, Indoxacarb and Spinosad (Kumar *et al.*, 2020). Pavithra *et al.* (2024) unveiled that field collected *P. absoluta* population from 10 south Indian locations exhibited less than 5-fold resistance ratio for chlorantraniliprole, cyantraniliprole, spinosad, indoxacarb, flubendiamide, acetamiprid and imidacloprid.

Apart from India, worldwide researches also accentuated the escalation of insecticide resistance in *P. absoluta*. In Chile, field-collected populations of *P. absoluta* exhibited reduced susceptibility to spinosad, showing significantly lower mortality than the susceptible strain (Reyes *et al.,* 2011).

Between 2010 and 2011, Brazilian populations demonstrated resistance levels of 8- to 93-fold for spinosad and 1.5- to 7-fold for spinetoram (Campos *et al.,* 2015). In Greece, field populations showed 2- to 14-fold resistance to chlorantraniliprole and 2- to 11-fold resistance to flubendiamide and indoxacarb (Roditakis *et al.,* 2012; Roditakis *et al.,* 2015). Brazilian, Spanish, and Italian populations also reported low levels of resistance to diamide insecticides (Roditakis *et al.,* 2013). A study from Turkey revealed that the *P. absoluta* population from Aydın had higher resistance to indoxacarb, metaflumizone,

Table 3. Relative toxicity of different insecticides on *P. absoluta*

S. No.	Location	LC_{50} (ppm)	Fiducial limits (95 %)		LC_{90} (ppm)	Fiducial limits (95 %)		Slope function (± SD)	Chi-square (df:13)	Ht	RR
			Lower	Upper		Lower	Upper				
A.) Susceptible strain											
1	Chlorantraniliprole 18.5 SC	3.152	1.398	5.964	16.446	13.261	20.338	2.884 ± 0.344	3.265	1.011	-
2	Cyantraniliprole 10.25 SC	6.015	4.087	8.625	20.232	17.212	23.648	2.999 ± 0.242	3.827	0.294	-
3	Flubendiamide 480 SC	6.502	5.615	8.340	26.645	20.259	40.275	3.194 ± 0.271	12.891	0.992	-
4	Indoxacarb 14.5 SC	5.980	4.226	4.226	25.127	20.687	31.364	2.325 ± 0.277	7.319	0.746	-
5	Emamectin benzoate 5 SG	6.851	5.577	8.175	24.433	18.723	36.790	2.310 ± 0.298	9.573	0.736	-
6	Lambda-cyhalothrin 5 EC	7.650	6.396	9.862	33.126	25.129	49.437	3.199 ± 0.248	6.215	0.342	-
7	Spinosad 45 SC	4.981	4.620	6.839	21.002	15.684	31.768	3.250 ± 0.281	4.126	0.317	-
8	Profenofos 50 EC	183.800	153.593	211.885	451.611	369.985	541.978	4.282 ± 0.480	12.335	0.449	-
B.) Belagavi field population											
1	Chlorantraniliprole 18.5 SC	60.631	41.123	74.507	357.662	243.407	678.772	1.543 ± 0.482	8.647	0.906	19.24
2	Cyantraniliprole 10.25 SC	39.987	32.691	47.179	112.800	88.301	170.058	2.145 ± 0.371	14.504	1.116	6.65
3	Flubendiamide 480 SC	32.378	25.457	41.651	196.521	134.472	246.087	1.468 ± 0.214	7.468	0.688	4.96
4	Indoxacarb 14.5 SC	20.609	13.768	27.824	112.079	91.805	140.306	1.717 ± 0.196	4.240	0.326	3.45
5	Emamectin benzoate 5 SG	46.821	36.192	58.729	211.925	181.487	365.488	1.714 ± 0.223	5.549	0.427	6.83
6	Lambda-cyhalothrin 5 EC	56.294	46.448	66.202	164.687	133.431	222.370	2.749 ± 0.323	10.298	0.792	7.36
7	Spinosad 45 SC	27.107	21.600	32.341	90.583	78.482	129.331	2.151 ± 0.294	5.240	0.403	5.44
8	Profenofos 50 EC	1350.22	1252.49	1617.99	2456.89	2580.58	3675.83	3.847 ± 0.690	8.977	0.921	7.35

Note: ppm- Parts per million, SD- Standard deviation, df- Degrees of freedom, Ht- Heterogeneity, RR- Resistance ratio
RR- LC_{50} of field population / LC_{50} of susceptible population

spinosad, and chlorantraniliprole compared to the Urla population (Yalcin *et al.,* 2015). In Kuwait, resistance to flubendiamide and chlorantraniliprole initially appeared at 3- and 4-fold levels, which later increased to 750- and 860-fold after 34 generations of selection (Jallow *et al.,* 2019). Likewise, a field-collected and laboratory-selected population in Pakistan exhibited high resistance to flubendiamide, with resistance ratios between 38- and 550-fold, while LC_{50} values for chlorantraniliprole, thiamethoxam, permethrin, abamectin, and tebufenozide were higher than those of the susceptible strain (Zhang *et al.,* 2022).

The overall findings of this study are in line with earlier reports worldwide, where increased resistance in *P. absoluta* has been attributed to elevated detoxification enzyme activity. Several studies have shown that metabolic enzymes like esterases, monooxygenases and glutathione S-transferases play a key role in resistance development. This indicates that the resistance levels observed here may similarly be linked to such enzyme-mediated mechanisms, as supported by previous research.

ACKNOWLEDGMENTS

The authors would like to thank University of Agricultural Sciences, Dharwad for providing necessary facilities during the study period.

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MS Received: 30 April 2025
MS Acceptance: 28 May 2025

Pest Management in Horticultural Ecosystems
Vol. 31, No.1 pp 67-70 (2025)
DOI Number : 10.5958/0974-4541.2025.00021.4

Population dynamics of *Chrysoperla zastrowi sillemi* (Esben-Petersen) fed with different hosts: Prospects for mass rearing and augmentative release

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ABSTRACT: Accurate demographic projections are essential for identifying prey diets that enhance predator efficiency in augmentative biological control. The population of lacewing, *Chrysoperla zastrowi sillemi* (Esben-Petersen) (*CZS*) was projected on four hosts including sterilized and unsterilized *Corcyra cephalonica* eggs, *C. cephalonica* neonates, and *Tribolium castaneum* using TIMING-MSChart program. The largest adult population of *C. zastrowi sillemi* was noted when reared on unsterilized eggs, reaching around 57000 adults after 60 days, compared to 51000 adults when reared on sterilized eggs. Population projection curves confirmed a faster build-up on unsterilized eggs, primarily due to enhanced juvenile survival and early adult fecundity. However, reliance on unsterilized eggs entails cannibalism, biosecurity risks, including pathogen and parasitoid contamination. These findings demonstrate that diet quality decisively shapes predator demography and establish sterilized *C. cephalonica* eggs as the most practical and reliable prey resource for insectary production and augmentative release of *C. zastrowi sillemi*.

Keywords: Augmentative release, *Chrysoperla zastrowi sillemi,* life table, population projection,

INTRODUCTION

The green lacewings, *Chrysoperla* spp. (Neuroptera: Chrysopidae) are among the most important generalist predators used in integrated pest management (IPM) owing to their voracious feeding on soft-bodied insect pests such as aphids, mealybugs, whiteflies, thrips, and lepidopteran eggs (Smith and Jones, 2010; Zhao *et al.,* 2015). Among them, *Chrysoperla zastrowi sillemi* (Esben-Petersen) (*CZS*) has gained prominence in tropical and subtropical horticultural systems due to its strong reproductive capacity, ecological adaptability, and compatibility with sustainable pest management strategies (Kumar *et al.,* 2018; Oliveira *et al.,* 2020). As interest in environmentally friendly alternatives to chemical pesticides rises, augmentative biological control utilizing lacewing predators is becoming ever more important. The success of augmentative programs, however, is critically dependent on the ability to mass-produce predators at low cost, high quality, and in a biosecure manner (Van Lenteren, 2012). Currently, mass rearing of *CZS* largely relies on *Corcyra cephalonica* eggs as the principal factitious diet. Although unsterilized eggs support rapid predator multiplication, they present serious drawbacks such as egg cannibalism, webbing, and contamination by microbial pathogens, parasitoids, and hyperparasitoids, which compromise colony health and sustainability (Patil and Deshmukh, 2013). Alternatives such as *C. cephalonica* neonates and *Tribolium castaneum* are sometimes explored, but their nutritional adequacy and efficiency in supporting predator growth remain poorly understood. Moreover, despite the recognized importance of diet quality, comprehensive demographic assessments quantifying its effect on lacewing performance are still limited.

In this study, we evaluated the life table parameters of *C. zastrowi sillemi* reared on four laboratory prey using the age-stage, two-sex life-table approach with the TWOSEX-MS Chart® software (Chi, 2020). In addition, population projection parameters were estimated with the TIMING-MS Chart® program to forecast predator growth and stage dynamics under different dietary regimes (Chi, 2021). Our integrative approach not only facilitates the identification of the most effective feeding regime for large-scale *C. zastrowi sillemi* rearing but also weighs practical concerns of colony health and biosecurity. Ultimately, the findings aim to inform improved protocols for sustainable mass-production and augmentative deployment of *C. zastrowi sillemi* in horticultural ecosystems.

MATERIALS AND METHODS

Experimental setup

The demographic parameters as well as population projection of *C. zastrowi sillemi* were studied at the Division of Genomic Resources, ICAR- National Bureau of Agricultural Insect Resources (NBAIR), Bengaluru, India. All experiments were conducted under controlled laboratory conditions of 25 ± 1 °C temperature, 65 ± 5% relative humidity (RH), and a photoperiod of 14L:10D. *Corcyra cephalonica* was reared in disinfected boxes (45 × 45 × 5 cm) using standardized artificial diet. While the adults of *C. zastrowi sillemi* were maintained in muslin-lined oviposition chambers and provided with cotton swabs soaked in water, 50% honey solution, a commercial protein supplement (Pfizer Ltd., Mumbai), and a 1:1 yeast-sucrose mixture. Castor pollen grains were placed in small containers at the corners of rearing boxes (20 × 16 cm), and perforated brown paper sheets were used to stimulate egg laying. Eggs were collected at two-day intervals and incubated until hatching.

Prey treatments

Four prey types were evaluated as larval diets, Sterilized *C. cephalonica* eggs (surface-sterilized with UV light exposure for 30 min), Unsterilized *C. cephalonica* eggs (freshly collected and used directly), *C. Cephalonica* neonates (newly hatched first-instar larvae) *T. castaneum* larvae (early instars (1-2 mm). Each *CZS* larva was provided ad libitum prey daily until pupation. Food was replenished daily, and leftover prey was removed.

Life-table study design

Newly hatched (< 12 h) *C. zastrowi sillemi* larvae were individually reared in plastic vials (4 × 5 cm) lined with moist filter paper to prevent desiccation. For each prey treatment, 120 individuals were monitored from egg hatching until adult death. Vials were checked every 24 h to record survival, developmental duration, and stage transitions (egg, larval instars, pupa, and adult). Daily fecundity, adult longevity, and pre-oviposition periods were recorded until female death.

Population projection

Stage-specific survival and fecundity data obtained from each prey diet were analysed using TIMING-MS Chart® (Chi, 2021) to generate population projection curves. Simulations of population growth and age-stage distribution of *Chrysoperla zastrowi sillemi* were conducted for 60 days under laboratory conditions to compare its long-term demographic performance on different diets. The program (Chi and Liu, 1985) estimates the population size that can be derived from life table parameters, with outputs including the total projected population and the age-stage structure, denoted as P(t) (insect population projection). This approach provides a dynamic visualization of how populations change over time under different diet treatments.

P(t): Insect population projection $P(t) = \sum_{j=1}^{m} \left(\sum_{x=0}^{\infty} c_{xj} n_{xj,t} \right)$

RESULTS AND DISCUSION

The *C. zastrowi sillemi* successfully completed development on all four prey types; however, significant differences were evident in survival and developmental times. Larvae reared on sterilized and unsterilized *C. cephalonica* eggs exhibited the shortest immature durations and highest survival (>85%), whereas those reared on *C. cephalonica* neonates and *T. castaneum* showed prolonged development with reduced survivorship (<60%). Faster development on *C. cephalonica* eggs indicates superior nutritional suitability, consistent with observations by Patil and Deshmukh (2013) that egg-based diets provide balanced nutrients for lacewing growth.

These results corroborate findings of Oliveira *et al*. (2020), who demonstrated that diet quality strongly influences reproductive capacity in *Chrysoperla* species. Enhanced fecundity on eggs reflects their high protein and lipid content, essential for oogenesis (Kumar *et al*., 2018).

Population projection simulations demonstrated a steeper increase in population size on unsterilized eggs, driven by early fecundity and higher juvenile survival. The largest adult population of *CZS* was noted when reared on unsterilized eggs, reaching around 57000 adults after 60 days, compared to 51000 adults when reared on sterilized eggs (Fig. 1 and 2). However, the difference with sterilized eggs diminished over time, suggesting that sterilized eggs can ensure comparable long-term productivity while mitigating risks of cannibalism,

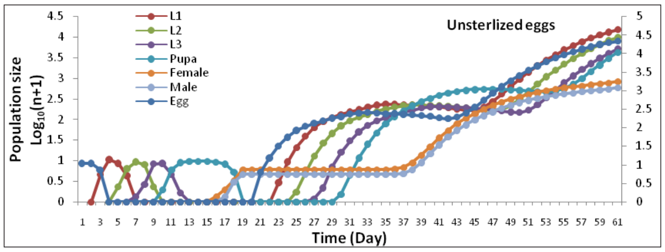

Fig. 1. Population projection of *Chrysoperla zastrowi sillemi* on unsterilized *Corcyra cephalonica* eggs

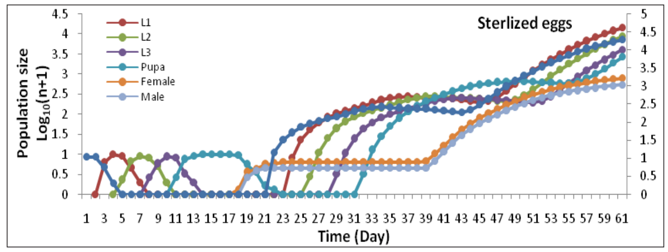

Fig. 2. Population predictions of *Chrysoperla zastrowi sillemi* on sterilized *Corcyra cephalonica* eggs

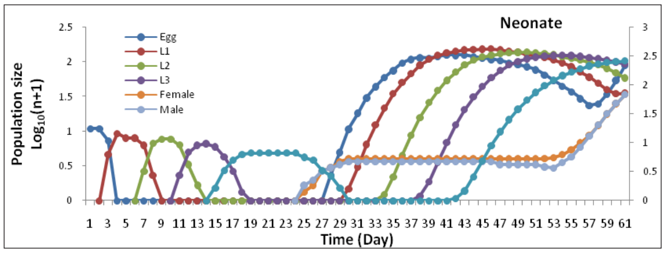

Fig. 3. Population predictions of *Chrysoperla zastrowi sillemi* on *Corcyra cephalonica* neonates

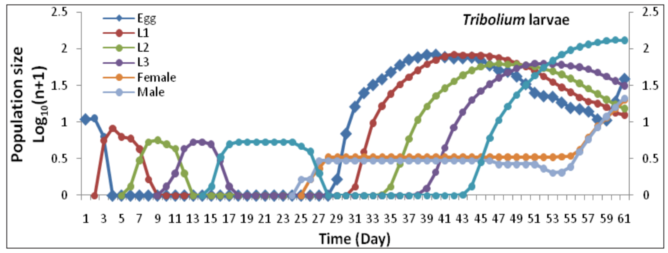

Fig. 4. Population predictions of *Chrysoperla zastrowi sillemi* on *Tribolium castaneum*

webbing, and contamination of unsterilized eggs. The lowest adult population was noted when reared on neonates of *Corcyra* and *T. castaneum* reaching around 600 and 300 adults after 60 days. The slower growth on neonates and *T. castaneum* highlights their unsuitability for large-scale rearing (Fig. 3 and 4).

Our population projection simulations revealed that (*CZS*) populations increased more rapidly when reared on unsterilized *C. cephalonica* eggs compared to sterilized eggs, largely due to higher juvenile survival and earlier fecundity. This trend is consistent with earlier studies on *Chrysoperla* spp., which repeatedly identified *C. cephalonica* eggs as the most suitable prey for mass rearing (Ramakrishnan *et al*. 1992; Balasubramaniam *et al*. 2001; Henry *et al*. 2010). Similar to our results, Harbi *et al*. (2025) reported that females reared on unsterilized *C. cephalonica* eggs exhibited higher fecundity than those reared on other prey sources. Although unsterilized eggs supported the highest adult population (57,000 after 60 days), our projections indicate that the difference with sterilized eggs (51,000) diminished over time. This suggests that sterilized eggs, despite initially reducing reproductive performance, can sustain comparable long-term productivity.

This observation agrees with findings of Atlihan and Chi (2008), who emphasized that prey quality strongly influences early growth trajectories but long-term fitness may stabilize across different diets. Moreover, using sterilized eggs has the practical advantage of reducing cannibalism, webbing, and contamination, a problem highlighted in mass-rearing facilities (Singh and Varma, 1986; Ghosh *et al*. 2016). Thus, our results support the recommendation that sterilized eggs are more suitable for large-scale and hygienic production systems. In contrast, the poorest performance was recorded on neonate larvae of *C. cephalonica* and *T. castaneum*, with adult populations reaching only 600 and 300 individuals, respectively, by day 60. The slower population growth on these diets corroborates earlier reports that chrysopids reared on neonates or flour beetle larvae experience prolonged development, reduced survival, and lower fecundity (Tauber *et al*. 2000; Chandran *et al*. 2018). The present results reinforce the conclusion that neonates and *T. castaneum* are unsuitable for large-scale rearing due to their poor nutritional quality and high handling costs. Overall, our findings strengthen the evidence that *C. cephalonica* eggs, particularly when sterilized, remain the most reliable food source for mass production of *CZS*, balancing biological performance with practical rearing considerations.

In conclusion, Sterilized *C. cephalonica* eggs provide a balanced solution for large-scale mass production of *CZS*, sustaining high demographic performance while minimizing risks of cannibalism, contamination, and handling challenges. Their practicality and reliability make them the most suitable prey resource for efficient insectary multiplication and augmentative biological control programs.

ACKNOWLEDGEMENT

The authors are thankful to the Head of the Department Entomology, UAS, Dharwad and Director, ICAR-NBAIR, Bengaluru, Karnataka and for providing the research facilities. The authors would like to express their gratitude to Prof. Hsin Chi (Laboratory of Theoretical and Applied Ecology, Department of Entomology, National Chung Hsing University, Taichung, Taiwan, Republic of China) for sharing the software (TWOSEX- MS Chart program) for data analysis. The authors express gratitude to Dr. Richa Varshany, Scientist at ICAR-NBAIR, Bengaluru, for supplying *Corcyra* eggs for growing the *Chrysoperla* predator for our study.

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MS Received: 12 May 2025
MS Acceptance: 08 June 2025

Pest Management in Horticultural Ecosystems
Vol. 31, No.1 pp 71-76 (2025)
DOI Number : 10.5958/0974-4541.2025.00001.8

Nano formulated chitosan for management of root knot nematode, *Meloidogyne enterolobii* in guava

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ABSTRACT: A study was conducted to assess the efficacy of chitosan nano formulation against root knot nematode, *Meloidogyne. enterolobii* infecting guava. Under *in vitro* conditions, the nano formulation exhibited strong nematicidal activity. In glasshouse experiment, application of chitosan nano formulation @5ml/plant reduced the nematode population in soil by 64.52 per cent and the number of egg masses and adult female nematodes by 67.61 and 46.80 per cent respectively. Under field conditions, infective juvenile population in soil was reduced by 52.97 per cent compared to untreated control. In addition, it also resulted in 31.42 and 31.03 percent reduction in the number of egg masses and adult female nematodes in roots, respectively.

Keywords: Chitosan, nano formulation, guava, root knot nematode, *Meloidogyne enterolobi*

INTRODUCTION

Guava is a high value fruit that holds economic importance in tropical and subtropical regions (Jameison *et al.,* 2021). Guava root-knot nematode (*Meloidogyne enterolobii*) is a highly pathogenic and invasive nematode species. Farmers are even unaware about this nematode until galled roots observed during harvest (Schwarz *et al.,* 2019). It has a broad host range including many vegetable crops, ornamental plants and weeds. It has been identified as a high priority pest in the biosecurity plans for the ginger, papaya, potato, sweetpotato and vegetable industries (Schwarz *et al.,* 2020). Like other root-knot nematode species, guava root-knot nematode induces galls on the roots of infected plants. In severe cases, extremely large and numerous galls can be found. Above-ground symptoms include stunted growth, wilting and leaf yellowing (Collet, 2020). Crop yield can be drastically reduced, and the quality of fruits severely affected. It can reduce the yield of about 65% which is severe root galling than the other root knot nematode species (Castagnone-Sereno and Castillo, 2014). In addition, guava root-knot nematode infection may favour further attacks on roots by secondary plant pathogens, such as root-rotting fungi (Khan *et al.,* 2022). Guava root-knot nematode is very damaging due to its ability to develop and reproduce on crops that are resistant to other species of *Meloidogyne* (Selvam *et al.,* 2025).

Nematicides are a widely used means of managing root knot nematodes. However, chemical application is discouraged due to potential risks to the environment and human health (Elgawad *et al.,* 2024). Chitosan is a naturally occurring polysaccharide obtained from chitin, which is a major structural component in the exoskeletons of crustaceans and insects, fungal cell walls, and fish scales. Structurally, it is a cationic polymer made up of (1–4)-2-amino-2-deoxy-β-ᴅ-glucan units. Its favorable characteristics—such as responsiveness to pH, compatibility with biological systems, and inherent bioactivity—make it more appealing for various applications than chitin itself (Shivasankari *et al.,* 2017). Chitosan is used in plant protection against numerous pests and diseases, as well as in preened post-harvest, as microbial biocide (bio-agent) by increasing the antagonist microorganism action, supports beneficial plant microorganism symbiotic relationships and plant growth regulation and development. Chitosan nanoparticles are used as nanopesticides and carriers of fungicides, insecticides, herbicides, plant hormones, elicitors, and nucleic acids (Hijazi *et al.,* 2019; Mohan *et al.,* 2024). This study was conducted to Application of chitosan nanoformulation, which significantly reduces gall formation, nematode population density, and improves plant growth parameters in guava infected by *M. enterolobii* compared to untreated controls.

MATERIALS AND METHODS

Chitosan nano formulation was prepared by ionic gelation method as described by Mouniga *et al.*(2023). The size and stability of the nano formulation were determined by using a Particle size analyzer.Root knot nematode *M.enterolobii* culture was obtained from the collection maintained at the Department of Nematology, Tamil Nadu Agricultural University, Coimbatore

Invitro study on the effect of chitosan nano formulation on *Meloidogyne enterolobii*

Effect of chitosan 1% nano formulation on hatching of eggs

Egg masses of *M. enterolobii* were sterilized with 0.5% sodium hypochlorite solution for 1 minute. Different concentrations *viz.,* 25%, 50 %, 75% and 100% were prepared from the 1% chitosan nano formulation. From each concentration, 2ml was taken in a 5cm diameter Petri plate. One egg mass of root knot nematode was placed in the Petri dish. The experiment was conducted in a Completely Randomized Block Design with five treatments and four replications were maintained for each treatment. Numbers of hatched juveniles were observed at different time intervals *viz.,* 24 h, 48 h and 72 h. Egg hatching study was evaluated by the Abbott formula

Juvenile mortality test

Freshly hatched juveniles (J2) were used for juvenile mortality studies. Different concentrations *viz., viz.,* 25%, 50 %, 75% and 100% were prepared from the 1% chitosan nano formulations. From each concentration, 1ml was taken in a 5cm diameter Petri plate to which 100 numbers infective juveniles (J2) were added. Totally five treatments and four replications were maintained in Completely Randomized Block Design.Numbers of dead juveniles were observed during 24 h, 48 h and 72 h time intervals and estimated by Abbott formula

Evaluation under glasshouse condition

A trial was conducted in Nematology Department Glass house, TNAU, Coimbatore. Sterilized pot mixture was taken in earthen pots. Guava seedlings were procured from TNAU orchard. Infective juveniles of root knot nematode *M.enterolobii* were inoculated @ 2 /g of soil after 15 days of planting. The experiment was conducted in a Randomized Block Design with five treatments (Table 1) and four replications were maintained for each treatment. The treatments were applied seven days after nematode inoculation. Observation on plant growth and nematode population in soil and roots were recorded 90 days after application of the treatments.

Field Evaluation

Field trial was conducted in a two-year-old guava plantation with incidence of *M.enterolobii*, at Coimbatore district, Tamil Nadu. The experiment was conducted in a Randomized Block Design with five treatments and four replications were maintained for each treatment. The pretreatment nematode population in soil was uniform throughout the experiment area with 200 guava trees. Ten trees were selected for each replication. Observation on plant growth and nematode population in soil and roots were recorded 90 days after application of the treatments. The treatments (Table 1) were applied as soil drench.

RESULTS AND DISCUSSION

Invitro study on the effect of chitosan nano formulation on *M. enterolobii*

From the observation, the chitosan nanoformulation at 100% concentration exhibited the highest efficacy, completely inhibiting egg hatching of *Meloidogyne enterolobii* when compared to the untreated control. The 75% concentration also proved to be highly effective, resulting in a substantial reduction in egg hatch ranging from 84.39% to 94% within 24 to 72 hours of exposure. In contrast, the lower concentrations (25% and 50%) showed a marked inhibition in egg hatching at 24 hours post-treatment; however, their efficacy declined over time. These results are consistent with findings reported by Ozdemir *et al.* (2022), who noted significant nematicidal activity of 2% chitosan formulations against nematode eggs. Further experiment outcome of Alfy *et al.* 2020 showed egg hatching inhibition 95.3%. after 72 hrs. This may be due to electrostatic interactions, as chitosan is positively charged and the surface of nematode eggs is negatively charged (Rabea and Badawy, 2003). Similarly juvenile mortality evaluated at the same concentrations indicated that at 100% concentration of chitosan nanoformulation caused 97.10% mortality of second-stage juveniles (J2) after 72 hours. The 75% concentration also exhibited strong nematicidal activity,

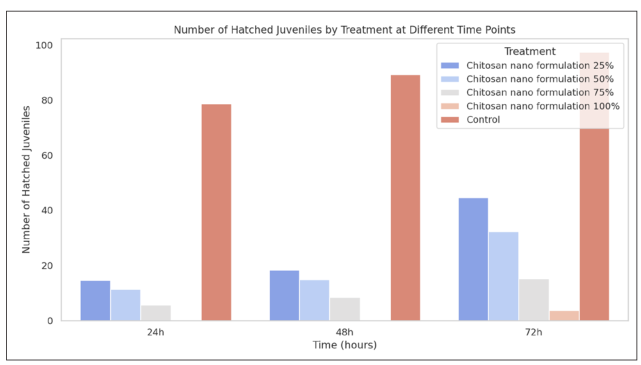

Fig.1. Effect of chitosan nano formulation on egg hatching of *M.enterolobii*

Table 1. Effect of Chitosan nano formulation on plant growth and population of *Meloidogyne enterolobii* in guava under pot culture condition (Mean of four replications)

Treatment details	Shoot length (cm)	Root length (cm)	Gall index	No. of egg mass/ g root	No. of female nematodes/ g root	Nematode population/ 200 cc soil
Chitosan nano formulation @ 5ml/plant at planting and 30 DAP	59.62 (40.05)	26.87 (56.95)	2	8.5 (67.61)	18.75 (46.80)	96.5 (64.52)
Pochonia chlamydosporia @ 2.5kg/ha at planting and 30 DAP	56.05 (31.66)	21.62 (26.28)	2	9.5 (63.8)	20 (56.73)	90 (66.91)
Purpureocilium lilacinum @ 2.5kg/ha at planting and 30 DAP	46.25 (8.64)	20.87 (21.90)	3	8.75 (66.66)	21 (40.02)	102.25 (62.4)
Fluropyram 34.48% EC	63 (47.99)	29.87 (74.47)	2	6.75 (74.28)	14.25 (59.57)	62.75 (76.93)
Untreated control	42.57	17.12	5	26.25	35.25	272
SE (d)	1.67	1.34	-	1.34	1.65	3.57
CD (0.05)	3.34	2.68	-	2.68	3.30	7.14

Table 2. Effect of Chitosan nano formulation on plant growth and population *Meloidogyne enterolobii* in Guava under field condition (Mean of four replications)

Treatment details	Gall index	No. of egg mass / g root	No. of female nematodes / g root	Soil nematode population/ 200 cc soil
Chitosan nanoformulation @ 5ml/plant	2	24 (31.42)	30 (31.03)	158 (52.97)
Pochonia chlamydosporia @ 2.5kg/ha	2	25 (28.57)	31.25 (28.16)	159.5 (52.52)
Purpureocilium lilacinum @ 2.5kg/ha	3	26.5 (24.28)	30 (31.03)	159.25 (52.6)
Fluropyram 34.48% EC @500ml/acre	2	19.75 (43.57)	24 (44.82)	134 (60.11)
Untreated control	5	35	43.5	336
SE (d)	-	1.42	1.99	4.02
CD (P=0.05)	-	2.84	3.98	8.04

inducing 63.22% to 84.31% mortality over the 24–72 hour exposure period. Even the lower concentrations (25% and 50%) were effective in causing statistically significant mortality of *M. enterolobii* juveniles. These observations align with the results of Khan *et al.* (2021), who reported highest juvenile mortality at 2500 ppm chitosan concentration. Similarly, Alfy *et al.* (2020) reported that chitosan nanospheres at 2000 ppm inhibited *M. incognita* egg hatching by 95.3% after 72 hours and resulted in 77.5% juvenile mortality, which confirm the current findings. The observed nematicidal activity of chitosan nanospheres leading to disruption of membrane integrity and leakage of intracellular proteinaceous contents of juveniles, as previously described by Rabea and Badawy (2003).

Evaluation under glasshouse conditions

Among the various treatments assessed, the emulsifiable concentrate (EC) formulation of fluopyram demonstrated the most pronounced effect on plant growth, resulting in a 47.99% increase in shoot length and a 74.47% increase in root length compared to the untreated control. Some recent studies have also reported that fluopyram enhances tomato growth and yield (Ji et al., 2019). Additionally, Li *et al.* (2020) reported that fluopyram application contributed

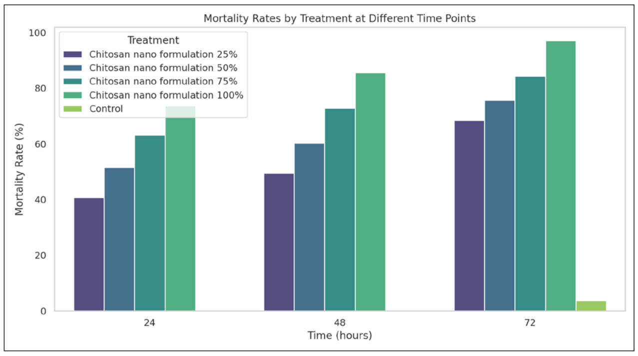

Fig. 2. Effect of chitosan nano formulation on *M.enterolobii* infective juveniles

significantly to overall plant growth.This growth-promoting effect may be partially attributed to fluopyram's potential to stimulate beneficial soil microbial activity, which in turn could contribute to improved plant health and productivity (Sun *et al.,* 2020). Chitosan nanoformulation was the next most effective, promoting shoot and root growth by 40.05% and 56.95%, respectively. According to Jail *et al.,* 2014 chitosan application increased the plant growth fruit yield by inducing increased the activity phytoalexins. It acts as phytostimulant because it reduces ROS formation and improve defense system in plants (Ullah *et al.,* 2023). The biocontrol agents *Pochonia chlamydosporia* and *Purpureocillium lilacinum* also enhanced plant development, with *P. chlamydosporia* increasing shoot length by 8.64% and root length by 21.9%, and *P. lilacinum* by 31.66% and 26.28%, respectively. These findings are in agreement with the report by Khan *et al.* (2023), who highlighted the growth-promoting effects of *P. lilacinum*, including improved biomass accumulation and enhancement of photosynthetic pigments. In terms of nematode suppression, the chitosan nanoformulation reduced the population of *Meloidogyne enterolobii* juveniles in the soil by 64.52% relative to the untreated control. Furthermore, it reduced the number of egg masses and adult females in the roots by 67.61% and 46.80%, respectively. Despite its growth-promoting potential, fluopyram was superior in reducing nematode infestation in both soil and root systems by affecting ubiquone binding site which blocks electron flow between mitochondrial membrane. Similarly, the biocontrol agents showed notable efficacy in nematode suppression. *P. chlamydosporia* decreased the soil nematode population by 66.91%, the number of egg masses by 66.66%, and the root population by 56.73%. *P. lilacinum* followed closely with reductions of 62.40%, 63.8%, and 40.02% in soil nematodes, egg masses, and root populations, respectively.

These findings are supported by those of López *et al.* (2024), who confirmed fluopyram's superior nematicidal activity among chemical treatments. The current results also align with those of Özdemir *et al.* (2022), who reported that chitosan at a 1% concentration significantly enhanced plant growth and reduced nematode populations without phytotoxic effects. Khalil *et al.* (2022) also observed a 45–66% reduction in nematode populations following chitosan treatment. The efficacy of *P. chlamydosporia* in decreasing nematode density was similarly documented by Arunachalam *et al.* (2025), while *P. lilacinum* was shown by Khan *et al.* (2023) to reduce both nematode populations and gall formation.

Field evaluation

The experiment revealed fluopyram resulted in the highest efficacy, enhancing plant growth parameters by 48% and reducing the nematode population by 60% compared to the untreated control. This was followed by the chitosan-based formulation, which improved plant growth by 40–56% and reduced the nematode population by 53%. *Pochonia chlamydosporia* demonstrated a 31% increase in plant growth and a 52% reduction in nematode population, while *Purpureocillium lilacinum* showed the least impact, with a 21% improvement in plant growth and a 52% reduction in nematode infestation**.**The nematode population also indicates the population reduction of J2 and egg mass count. Hence these reductions, where moderate compared to fluopyram, highlight the potential of these biocontrol agents as sustainable components of integrated nematode management programs. The nematicidal effect of chitosan is closely linked to its biochemical interactions in the soil. Chitosan application enhances the population of chitinolytic microorganisms, which produce chitinase enzymes that degrade the chitin-rich egg shells and juvenile cuticles of root-knot nematodes (Abd El-Aziz and Khalil, 2020). Furthermore, chitosan's ability to induce systemic resistance in plants and generate nematotoxic compounds upon decomposition contributes to its inhibitory effects on nematode development and reproduction (Asif *et al.,* 2017). Previous studies evidence the present findings. Mouniga *et al.* (2023) reported that chitosan nanospheres exhibited strong nematicidal properties against *M. incognita* under laboratory, greenhouse, and field conditions. Alfy *et al.* (2020) demonstrated that chitosan nanoparticles at 2000 ppm treatment led to a 78% reduction in soil nematode populations and a 98% reduction in root infestation in tomato plants, along with enhanced plant growth metrics.

CONCLUSION

Preliminary studies have indicated that chitosan nano formulation to be very effective against root knot nematode *M.enterolobii* in Guava. However, the long-term effect of chitosan nano formulation and its compatibility with nematode biocontrol agents like *Pochonia chlamydosporia* has to be evaluated in order to develop a holistic and sustainable management practice for root knot nematode *M. enterolobii* in guava.

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MS Received: 12 May 2025
MS Acceptance: 16 June 2025

Pest Management in Horticultural Ecosystems
Vol. 31, No.1 pp 77-85 (2025)
DOI Number : 10.5958/0974-4541.2025.00015.1

In-vitro evaluation of fungicide combinations against fruit rot (*Colletotrichum truncatum*) in chilli

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ABSTRACT: The present investigation was carried out *in vitro* to evaluate effectiveness of combination of two fungicide products in comparison to individual components against fruit rot causing organism, *Colletotrichum truncatum* (Schwein.) Andrus & W.D. Moore [synonym *Colletotrichum capsici* (Syd. & P. Syd.) E.J. Butler & Bisby] in chilli crop. The effectiveness of two fungicides, Kresoxim methyl 44.3% SC @ 80, 40, 20, 10, 5 and 2.5 ppm and Tebuconazole 25.9% EC @ 20, 10, 5, 2.5, 1.25 and 0.625 ppm along with untreated control were assessed using food poison technique. Kresoxim methyl 44.3% SC at 80 ppm exhibited significantly low radial growth of the pathogen 0.93, 1.57 and 2.73 cm and resulting in 78.52, 78.78 and 67.88% growth inhibition at 3, 7 and 10 days after exposure, respectively. The lowest radial growth in Tebuconazole 25.9% EC at 20 ppm was 0.32, 0.60 and 0.92 cm with 94.32, 91.67 and 88.82% reduction in radial growth over control at 3, 7 and 10 days after exposure, respectively. The combination effect of Kresoxim methyl 44.3% SC + Tebuconazole 25.9% EC at different levels (40+10, 40+5, 20+10, 20+5, 10+10 and 10+5 ppm), showed that the combination at 40+10 ppm level exhibited minimal radial growth of pathogen 0.45, 0.70 and 1.17 cm with 90.36, 90.54 and 86.12% growth inhibition over control at 3, 7 and 10 days of experimentation, respectively. The present investigation extends opportunities for field evaluation of Kresoxim methyl 44.3% SC + Tebuconazole 25.9% EC as tank mix for the control of fruit rot disease of chilli crop.

Keywords: *In vitro*, kresoxim methyl, tebuconazole, chilli, *Colletotrichum truncatum*

INTRODUCTION

Chilli (*Capsicum annum* L.), a solanaceous crop is grown world over and consumed in the form of green vegetables as well as spices. A rich source of vitamins, pungency and flavours make it popular in almost all the household to use in one or the other form. The crop suffers from a number of insect pests and diseases during different phenological phases of the crop growth. Many fungal species are on record causing damping off or seedling rot at seedling stage, leaf spot, die back, fruit rot or anthracnose at fruiting stage, which hamper marketable quality and rest in higher economical loss to the grower. Anthracnose is one of the severe fungal diseases affecting chilli crop. In India, it is mainly caused by *Colletotrichum truncatum* (Schwein.) Andrus & W.D. Moore [synonym *Colletotrichum capsici* (Syd. & P. Syd.) E.J. Butler & Bisby] and by other species *C. acutatum* and *C. gloeosporioides*. It is characterized by sunken necrotic lesions at different stages of the crop and spreads widely during high humid conditions and leaves no scope to check its incidence in a short time.

To control the anthracnose/fruit rot disease on chilli crop, a number of fungicides have been approved by Govt. of India under the Insecticides Act, 1968 like, Azoxystrobin 23% SC, Chlorothalonil 75% WP, Difenoconazole 25% EC, Kresoxim methyl 44.3% SC, Pyraclostrobin 20% WG, Tebuconazole 25.9% EC and 25% WG, Thiophanate methyl 41.7% SC etc. In addition, a number of combination products of these and other fungicides also have been approved. The combination products comprising Kresoxim methyl as one of the constituents registered and approved are Kresoxim methyl 15% + Chlorothalonil 56% WG, Kresoxim methyl 18% + Mancozeb 54% WP, Kresoxim methyl 40% + Hexaconazole 8% WG, Kresoxim methyl 6% + Thifluzamide 26% SC and Flubendiamide 7.5% + Kresoxim methyl 37.5% SC. Similarly, the combination products of Tebuconazole as one of the constituents registered are Tebuconazole 6.7% + Captan 26.9% SC, Tebuconazole 10% + Sulphur 65% WG, Tebuconazole 50% + Trifloxystrobin 25% WG, Tebuconazole 15% + Zineb 57% WDG, Tricyclazole 18.0% + Tebuconazole 14.4% SC, Prochloraz 5.7% + Tebuconazole 1.4% ES and Prochloraz 24.4% + Tebuconazole 12.1% EW.

The *in vitro* studies on Azoxystrobin 11% + Tebuconazole 18.3% SC, Tebuconazole 50% + Trifloxystrobin 25% WG against *C. gloeosporioides* have been reported by Golakiya *et al.* (2020). Chandini *et al.* (2022) investigated Azoxystrobin 11% + Tebuconazole 18.3% w/w SC, Prochloraz 24.4% + Tebuconazole 12.15% w/w EW, Tebuconazole 50% + Trifloxystrobin 25% WG against *C. capsici*. Mondal and Sarkar (2023) evaluated Kresoxim methyl 40% WG + Hexaconazole 8% WG against fungal diseases like leaf spot, powdery mildew, twig blight and anthracnose in chilli crop. The present studies were undertaken for the compatibility of Kresoxim methyl and Tebuconazole against fruit rot causing organism in chilli under laboratory conditions.

MATERIALS AND METHODS

The chilli crop cultivated at Experimental Research Farm, IPFT, Gurugram during Kharif season 2024 was visited regularly and on appearance of disease symptoms on leaf, stem and formation of concentric ring on the fruit surface, the rotten fruits were collected in perforated polythene bags and brought to the laboratory for isolation, identification and purification of the pathogen.

Preparation of Potato Dextrose Agar medium and isolation of pathogen

The laboratory glasswares washed properly with soap solution were sterilized keeping inside hot air oven at least for 2 hours at 165 ºC. Potato Dextrose Agar (PDA) 40 g was taken in 1000 ml capacity conical flasks and added sterilized distilled water up to the mark. The contents were mixed thoroughly using magnetic stirrer for minimum 10 minutes. The mixture was then transferred to four conical flasks of 250 ml capacity and the mouth was plugged with cotton, which was subsequently wrapped with aluminum foil. The flasks containing the media were then autoclaved at 121 ºC and 15 psi for sterilization and media was poured in Petri plates inside laminar air flow. The diseased fruit samples collected from the field were washed with tap water and surface dried using sterilized tissue paper. The fruits were cut into small pieces (~3-5 mm) using sterilized blade and treated with 2% sodium hypochlorite solution and then washed thrice by distilled water. The small cut pieces were transferred aseptically on sterilized PDA Petri plates and incubated in BOD (Biochemical Oxygen Demand) incubator at 25 ^{o}C and 65 ± 5% RH for 5 to 7 days.

Purification and identification of pathogen

The Petri plates were examined for uniform pathogen colony growth and for any visible contamination. The contaminated Petri plates, were instantly discarded. The pathogen was purified by single hyphal tip method. For this, single hypha of the pathogen which showed uniform growth was transferred and cultured on new PDA Petri plates. The pathogen slowly spread out with its hyphal growth from the center to periphery of the Petri plates in search of nutrients and uniformly colonized the Petri plates. For identification of pathogen, a single hyphal strand was isolated from the fungal colony, fixed on a glass slide and observed under compound microscope and electron microscope for their conidia. The falcate conidia were examined for other morphological and cultural characters and isolated pathogen was identified as *Colletotrichum truncatum* following Mongkolporn *et al.* (2010); Prajapati *et al.* (2020); Sawant *et al.* (2023); R. S. Singh (1978) and Than *et al.* (2008). The hyphal tips were carefully transferred to PDA and maintained in BOD incubator at 25 ± 2^{o}C and 65 ± 5% RH for further use and PDA slants were also preserved in refrigerator at 4 ^{o}C for later studies. The sub-culturing of the isolated pathogen was done on monthly basis to maintain the culture for further scientific research.

Fungicidal treatments

The commercial formulation of fungicides Kresoxim methyl 44.3% SC and Tebuconazole 25.9% EC were used for the studies by food poisoning technique. The preliminary non replicated effective concentration range finding experiment of the two products was conducted using 400, 200, 100, 50, 25 and 12.5 ppm concentrations and based on the fungal growth, the main experiment was laid down. Different base concentrations 8000, 4000, 2000, 1000, 500 and 250 ppm of Kresoxim methyl 44.3% SC and 2000, 1000, 500, 250, 125 and 62.5 ppm of Tebuconazole 25.9% EC (based on the active ingredient of respective product) prepared in distilled water. Further to get the requisite working concentrations 80, 40, 20, 10, 5 and 2.5 ppm of Kresoxim methyl and 20, 10, 5, 2.5, 1,25 and 0.625 ppm of Tebuconazole, 1 ml of each base concentration was added to 100 ml luke warm PDA before solidification and poured in to the Petri plates. First experiment was conducted taking above respective concentrations. The pathogen discs (5 mm dia) were transferred aseptically under laminar air flow at the centre of all the Petri plates. The untreated

Petri plates were taken as control and each treatment was replicated thrice. The experiment set up was placed in BOD incubator at 25 ± 2°C and 65 ± 5% RH. The observations for fungal radial growth were recorded after 3, 7 and 10 days. Based on the results of first experiment, moderately effective concentrations were considered for second experiment to evaluate effectiveness of Kresoxim methyl 44.3% SC + Tebuconazole 25.9% EC combinations in different compositions *viz*., 40+10, 40+5, 20+10, 20+5, 10+10 and 10+5 ppm. The same method as stated above for first experiment was followed to prepare working concentrations and experiment set up for second experiment as well. The percent inhibition of radial growth of the fungus was calculated by using the following formula:

$$Percent\ Inhibition = \frac{C - T}{T} * 100$$

Here,
C= control
T = Treatment

RESULTS AND DISCUSSION

The results of the antifungal activity of Kresoxim methyl 44.3% SC against the pathogen presented in Table 1 and fungal growth in Fig. 1, showed that the mycelial radial growth of the pathogen was efficiently checked at each concentration tested as compared to untreated control. The radial growth increased with the decrease in concentration of the product and ranged from 0.93 to 5.53 cm during the observation period. Higher radial growth 2.47, 4.20 and 5.53 cm was seen in 2.5 ppm treatment, whereas lowest growth was observed in 80 ppm 0.93, 1.57 and 2.73 cm after 3, 7 and 10 days of treatment, respectively. Overall, the growth of the fungus was significantly low in all the treatments as compared to untreated control which recorded highest growth 4.33, 7.40 and 8.50 cm after 3, 7 and 10 days, respectively. The per cent reduction in fungal growth calculated over untreated control presented graphically in Fig. 2, revealed that there was an increase in percent reduction of mycelial growth with increase in concentration of the product. The per cent reduction ranged 78.52-42.96%, 78.78-43.24% and 67.88-34.94% over control after 3, 7 and 10 days of treatment. Among the treatments, 80 ppm (78.52, 78.78 and 67.88%) and 40 ppm (72.98, 70.27 and 59.18%) of kresoxim methyl 44.3% SC exhibited higher percent growth inhibition of the pathogen, respectively.

Kresoxim methyl 50% SC (based on w/v) @ 400 and 500 ml/ha have been reported effective against fungal diseases like leaf spot, powdery mildew, twig blight and anthracnose in chilli crop (Mondal and Sarkar, 2023). Kresoxim methyl 44.3% SC (based on w/w) @ 500 ml/ha also found effective against die back and fruit rot of chilli (Azad *et al.*, 2016). Chu *et al.* (2022) reported that EC_{50} values of Kresoxim methyl against most of the *Colletotrichum gloeosporioides* isolates were higher than 500 µg a.i./ml (equivalent to > 500 ppm). Mandloi *et al.* (2023) have reported per cent inhibition of *C. truncatum*

Table 1. Effect of Kresoxim methyl 44.3% SC on radial growth of *Colletotrichum truncatum*

Treatment	Concentration (ppm)	Radial growth of pathogen (cm) (days after treatment)		
		3	7	10
T_1- Kresoxim methyl 44.3% SC	80	0.93 (0.97)	1.57 (1.25)	2.73 (1.65)
T_2- Kresoxim methyl 44.3% SC	40	1.17 (1.07)	2.20 (1.48)	3.47(1.86)
T_3- Kresoxim methyl 44.3% SC	20	1.30 (1.14)	2.47 (1.57)	3.93(1.98)
T_4- Kresoxim methyl 44.3% SC	10	1.53 (1.24)	2.80 (1.67)	4.27 (2.07)
T_5- Kresoxim methyl 44.3% SC	5.0	2.10 (1.45)	3.53 (1.88)	5.27 (2.29)
T_6- Kresoxim methyl 44.3% SC	2.5	2.47 (1.57)	4.20 (2.05)	5.53 (2.35)
T_7- Untreated control	--	4.33(2.08)	7.40 (2.72)	8.50(2.92)
S.Em ±		0.05	0.04	0.03
C.D (p=0.05)		0.14	0.11	0.08

Figures in the parentheses are square root transformed values

80 ppm | 40 ppm | 20 ppm | 10 ppm | 5 ppm | 2.5 ppm | Control

Fig. 1. Radial growth of *C. truncatum* in Kresoxim methyl 44.3% SC treatment at different concentration

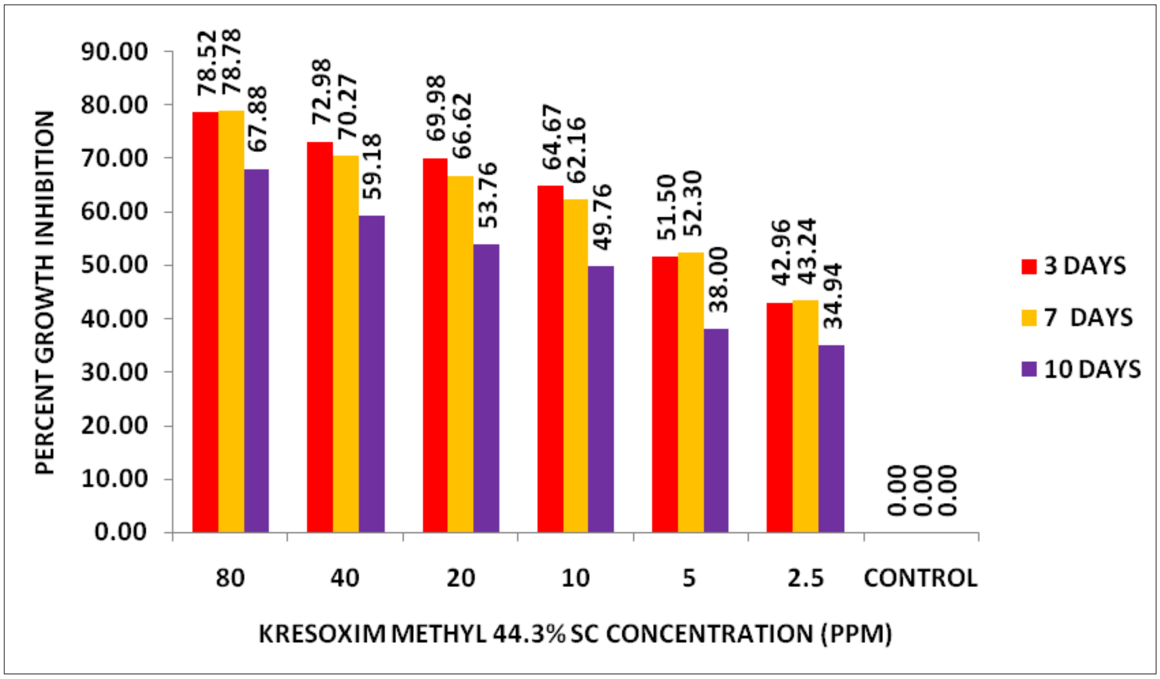

Fig. 2. Per cent growth inhibition of *C. truncatum* over control by Kresoxim methyl 44.3% SC

mycelial growth by 27.28, 30.35, 40.50 and 40.49% at 100, 250, 500 and 1000 ppm of Kresoxim methyl 44.3% SC after 7 days, which were comparatively low as compared to the present study, wherein the growth of the pathogen highly suppressed at 80 ppm and resulted in 78.78% reduction in radial growth. The reduction in mycelial growth of the pathogen by Kresoxim methyl (strobilurin compound) is attributed to be a quinone outside inhibitor, inhibiting mitochondrial respiration by blocking electron transfer between cytochrome b and cytochrome c_1 at the ubiquinol oxidizing site.

The antifungal activity of tebuconazole 25.9% EC against *C. truncatum* presented in table 2 and fungal growth in Fig. 3 showed that the mycelial radial growth of the pathogen was efficiently controlled at each concentration tested as compared to untreated control. The increase in radial growth was observed with decrease in concentration of the product, which ranged from 0.32 to 6.94 cm during the observation period. The radial growth 4.47, 5.76 and 6.94 cm in 0.625 ppm treatment were higher, whereas low growth was observed in 20 ppm 0.32, 0.60 and 0.92 cm after 3, 7 and 10 days of treatment, respectively. The growth of the fungus was significantly low in all the treatments when compared with untreated control where after 3, 7 and 10 days the growth recorded was quite higher 5.63, 7.20 and 8.23 cm, respectively. The per cent reduction in fungal growth in all the treatments calculated over untreated control has been presented in Fig. 4. The increase in percent reduction of mycelial growth was resulted with increase in concentration of the tested product. The per cent reduction after 3, 7 and 10 days of treatment ranged 94.32-20.60%, 91.67-20.00% and 88.82-15.67% over untreated control. Among the treatments, 20 ppm (94.32, 91.67 and 88.82%), 10 ppm (89.34, 90.14 and 86.27%) and 5 ppm (78.69, 82.22 and 80.07%) of tebuconazole 25.9% EC exhibited higher percent growth inhibition of the pathogen at 3, 7 and 10 days after treatment, respectively.

Table 2. Effect of tebuconazol 25.9% EC on radial growth of *C. truncatum*

Treatment	Concentration (ppm)	Radial growth of pathogen (cm) (days after treatment)		
		3	7	10
T_1 - Tebuconazole 25.9% EC	20	0.32 (0.57)	0.60 (0.77)	0.92 (0.96)
T_2 - Tebuconazole 25.9% EC	10	0.60 (0.77)	0.71 (0.84)	1.13 (1.06)
T_3 - Tebuconazole 25.9% EC	5.0	1.20 (1.09)	1.28 (1.13)	1.64 (1.28)
T_4 - Tebuconazole 25.9% EC	2.5	3.30 (1.82)	4.23 (2.06)	5.70 (2.39)
T_5 - Tebuconazole 25.9% EC	1.25	3.85 (1.96)	5.12 (2.26)	6.51 (2.55)
T_6 - Tebuconazole 25.9% EC	0.625	4.47 (2.11)	5.76 (2.40)	6.94 (2.63)
T_7 - Untreated control	--	5.63 (2.37)	7.20 (2.68)	8.23 (2.87)
S.Em ±		0.03	0.02	0.03
C.D (p=0.05)		0.09	0.07	0.09

Figures in the parentheses are square root transformed values

20 ppm | 10 ppm | 5 ppm | 2.5 ppm | 1.25 ppm | 0.625 ppm | Control

Fig. 3. Radial growth of *C. truncatum*in at different concentration of tebuconazole 25.9% EC treatment

Tebuconazole 25.9% EC @ 500 ml/ha reported to be effective against die back and fruit rot of chilli crop and more or less equally effective with Kresoxim methyl 44.3% SC @ 500 ml/ha (Azad *et al.*, 2016). *In vitro* evaluation of Tebuconazole 25.9% EC @ 100, 150 and 200 µg/ml (equivalent to 100, 150 and 200 ppm) has been found effective against four isolates of *C. capsici* (78.33 to 100.00% inhibition) by (Begum *et al.*, 2015). However, Tebuconazole has been reported to be effective against *C. capsici* with ED_{50} value of 12 µg/ml (12 ppm) by (Chander *et al.*, 2004). The present study corroborates the above findings where the growth of *C. truncatum* at 20 ppm resulted in reduction of radial growth up to 94.32%. The reduction in mycelial growth of the pathogen by Tebuconazole (a triazole compound) is attributed to be a sterol demethylation (ergosterol biosynthesis) inhibitor, which means it inhibit synthesis of ergosterol, affecting the cell walls of fungi and causing suppression of spore germination and fungus growth (Dong, 2024).

Machenahalli *et al.* (2021) reported tebuconazole 430 SC at 250, 500 and 1000 ppm effectively controlled coffee leaf blight pathogen *C. gloeosporioides in vitro* and (Ramesh *et al.*, 2020) reported that the product at 8.5 ml/10 lit was most effective against anthracnose caused by same pathogen in pomegranate under field conditions.

Kumbhar and More (2013) reported that under field conditions tebuconazole 25.9% EC effectively reduced the incidence (69.96%) and intensity (73.56%) of fruit rot caused by *C. capsici* in chilli crop. In the present study, tebuconazole at 20 ppm was found to be the best treatment in inhibiting the pathogen growth. (Golakiya *et al.*, 2020) reported cent per cent mycelial growth inhibition of *C. gloeosporioides* by Tebuconazole 25.9% EC @ 100, 250 and 500 ppm and also summarized those fungicides of triazole group were more effective as compared to strobilurin group. In the present study also, it was observed that the effectiveness of Tebuconazole

25.9% EC (triazole group) was far better than Kresoxim methyl 44.3% SC (strobilurin group) against *C. truncatum*.

The combination of kresoxim methyl 44.3% SC and Tebuconazole 25.9% EC to evaluate the anti-fungal activity, the respective intermediate effective doses 40 and 10 ppm were taken as the highest doses and other treatments were taken in different ratios. The data on *C. truncatum* mycelial radial growth presented in Table 3 and Fig. 5 showed that the radial growth of the fungi was significantly low in combination treatments of Kresoxim methyl 44.3% SC + Tebuconazole 25.9% EC as compared to control treatment. The radial growth was low in the treatment of Kresoxim methyl 44.3% SC + Tebuconazole 25.9% EC @ 40 + 10 ppm (0.45, 0.70 and 1.17 cm after 3, 7and 10 days, respectively) followed by dose rate @ 20 + 10 ppm (0.60, 0.93 and 1.20 cm). The per cent inhibition of fungal growth calculated over untreated control ranged from 90.36-68.52%, 90.54-77.03% and 86.12-69.51% after 3, 7 and 10 days of treatment (Fig. 6). Among the treatments, 40 + 10 ppm of Kresoxim methyl 44.3% SC + Tebuconazole 25.9% EC exhibited highest percent growth inhibition of the pathogen (90.36, 90.54 and 86.12%) followed by 20 + 10 ppm (87.51, 87.43 and 85.77%) over control, after 3, 7 and 10 days of exposure.

The radial growth in all the treatments represented an increasing trend with the time spent. But the rate of increase was different, which showed no trend in per cent inhibition in fungal growth. The combined impact of Kresoxim methyl and Tebuconazole by way of inhibiting mitochondrial respiration and ergosterol synthesis, respectively resulted in better effectiveness as compared to Kresoxim methyl 44.3% SC alone at corresponding concentrations, however found more or less equally effective with Tebuconazole 25.9% EC. The above findings corroborate to (Golakiya *et al.*, 2020) that trizole group of fungicides alone or in combination were resulted to be more effective based on Azoxystrobin 11% + Tebuconazole 18.3% SC and Tebuconazole 50% + Trifloxystrobin 25% WG *in vitro* evaluation at 100, 250, 500 and 1000 ppm and Tebuconazole 25.9% EC @ 100, 250 and 500 ppm with complete growth inhibition of *C. gloeosporioides*. On the other hand, observations made by (Chandini *et al.*., 2022) *in vitro* against *C. capsici* revealed that Tebuconazole 25.9% EC was more effective as compared to different combination products with Tebuconazole as one of the constituents (Azoxystrobin 11% + Tebuconazole 18.3% w/w SC, Prochloraz 24.4% + Tebuconazole 12.15% w/w EW, Tebuconazole 50% + Trifloxystrobin 25% WG). Singh *et al.* (2012) reported Trifloxystrobin + Tebuconazole combination to be effective *in vitro* with 100% inhibition of *C. gloeosporioides* at 500 ppm and Begum *et al.* (2015) against four isolates of *C. capsici* investigated that @ 50 to 200 µg/ml (equivalent to 50 to 200 ppm) of the product inhibited the mycelial growth from 79.4 to 100%. Kresoxim methyl 40% WG + Hexaconazole 8% WG @ 500 and 625 g/ha have been reported effective against fungal diseases like leaf spot, powdery mildew, twig blight and anthracnose in chilli crop (Mondal

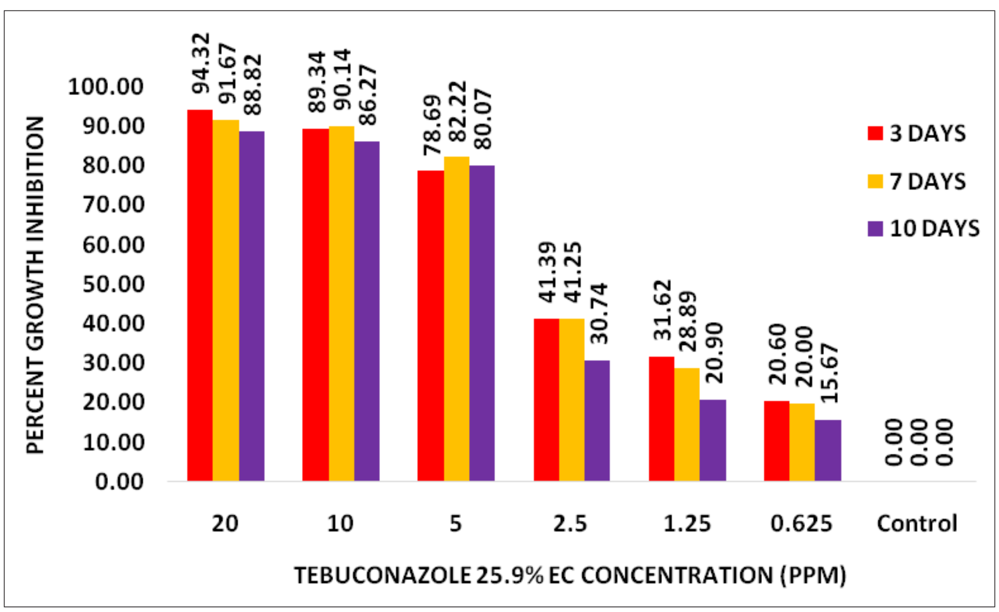

Fig. 4. Per cent growth inhibition of *C. truncatum* over control by Tebuconazole 25.9% EC

Table 3. Combined effect of Kresoxim methyl 44.3% SC + Tebuconazole 25.9% EC on radial growth of *C. truncatum*

Treatment	Concentration (ppm)	Radial growth of pathogen (cm) (days after treatment)		
		3	7	10
T_1 - Kresoxim methyl 44.3% SC + Tebuconazole 25.9% EC	40 +10	0.45 (0.67)	0.70 (0.83)	1.17 (1.08)
T_2 - Kresoxim methyl 44.3% SC + Tebuconazole 25.9% EC	40 + 5	0.67 (0.82)	1.47 (1.21)	1.60 (1.26)
T_3 - Kresoxim methyl 44.3% SC + Tebuconazole 25.9% EC	20 + 10	0.60 (0.77)	0.93 (0.96)	1.20 (1.09)
T_4 - Kresoxim methyl 44.3% SC + Tebuconazole 25.9% EC	20 + 5	0.85 (0.92)	1.37 (1.17)	1.87 (1.37)
T_5 - Kresoxim methyl 44.3% SC + Tebuconazole 25.9% EC	10 + 10	0.80 (0.89)	1.73 (1.32)	1.77 (1.33)
T_6 - Kresoxim methyl 44.3% SC + Tebuconazole 25.9% EC	10 + 5	1.47 (1.21)	1.70 (1.30)	2.57 (1.60)
T_7 - Untreated control	--	4.67 (2.16)	7.40 (2.72)	8.43 (2.90)
S.Em ±		0.02	0.03	0.02
C.D (p=0.05)		0.07	0.08	0.08

Figures in the parentheses are square root transformed values

40+10 ppm   40+5 ppm   20+10 ppm   20+5 ppm   10+10 ppm   10+5 ppm   Control

Fig. 5. Radial growth of *C. truncatumin Kresoxim* methyl 44.3% SC + Tebuconazole 25.9% EC treatment

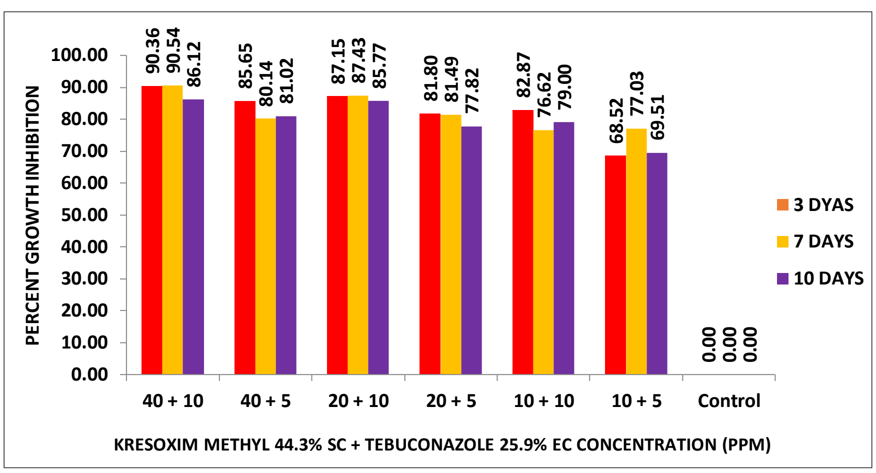

Fig. 6. Per cent growth inhibition of *C. truncatumover* control by Kresoxim methyl 44.3% SC + Tebuconazole 25.9% EC

and Sarkar, 2023). The *in vitro* results of the present study confirm the compatibility of Kresoxim methyl and Tebuconazole against *C. truncatum* and both the fungicides have a potential for controlling the diseases caused by the pathogen. However, it is imperative to evaluate the combination composition under field conditions as tank mix to find out the minimum effective dose for the control of fruit rot disease in chilli crop.

CONCLUSION

Kresoxim methyl 44.3% SC @ 2.5 to 80 ppm and Tebuconazole 25.9% EC @ 0.625 to 20 ppm were investigated *in vitro* by food poisoning method against the pathogen, *Colletotrichum truncatum* causing fruit rot disease in chilli crop. The concentrations 80 and 40 ppm of Kresoxim methyl 44.3% SC with 67.88-78.78% and 59.18-72.98% and 20, 10 and 5 ppm of Tebuconazole 25.9% EC with 88.82-94.32, 86.27-90.14% and 78.69-82.22%, respectively were quite effective to check the mycelial growth of the pathogen. The combination of Kresoxim methyl 44.3% SC + Tebuconazole 25.9% EC at different ratios were also investigated. The combination of these two products @ 40 + 10 ppm and 20 + 10 ppm, recorded minimal mycelial growth with growth inhibition 86.12-90.54% and 85.77-87.43%, respectively over control. The field evaluation of the combination product Kresoxim methyl 44.3% SC + Tebuconazole 25.9% EC as tank mix is further to be studied to find out the effective dose of the product to control fruit rot diseases of chilli crop.

ACKNOWLEDGEMENT

The authors are grateful to the Director, IPFT, Gurugram for encouragement and providing the necessary facilities.

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MS Received: 04 March 2025
MS Acceptance: 21 May 2025

Pest Management in Horticultural Ecosystems
Vol. 31, No.1 pp 86-93 (2025)
DOI Number : 10.5958/0974-4541.2025.00017.4

Occurrence of ginger foliar disease complex epidemics: *Xanthomonas* leaf blight, *Proxipyricularia* blast and *Colletotrichum* leaf spot in the Western Ghats of Karnataka, India

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ABSTRACT: Ginger (*Zingiber officinale* Roscoe) is one among the most valued and widely cultivated spice crops in the world. The major limitation to the production of ginger is its susceptibility to a wide range of pests and diseases. Intensive roving survey was conducted to know the disease severity and exact cause of ginger foliar disease complex in seven talukas *viz*., Shivamogga, Sagar, Soraba, Bhadravathi, Hosanagara, Thirthahalli and Shikaripura of Shivamogga district, Karnataka during June to July 2025. From this study we found three pathogens responsible for epidemics – Bacterial leaf blight caused by *Xanthomonas axanopodis pv. zingiberis* is the first report from India and world, *Proxipyricularia zingiberis* (=*Pyricularia zingiberis*) cause blast and *Colletotrichum zingiberis* cause leaf spot. Though, all the three pathogens present in 66 fields in 59 villages of seven talukas in moderate to severe form but leaf spot was in low to moderate form.

Key words: Ginger, *Xanthomonas* leaf blight, *Proxipyricularia* blast, *Colletotrichum* leaf spot, epidemics

INTRODUCTION

India is renowned throughout the world as "spice bowl" due to production and export of spices. The spices contribute 6.0 per cent to total export and 9.00 per cent to agriculture export (Spice Board India, 2024). Ginger (*Zingiber officinale* Roscoe) is a valuable rhizomatous spice crop known for its distinctive flavor, pungency and aroma. It is utilized in various products *viz*., wine, beer, carbonated beverages, cordials, confectionery, pickles and pharmaceuticals. Ginger belongs to Zingiberaceae family, it thrives in regions like tropical and subtropical (Kavitha & Thomas, 2008).

As per Dohroo *et al*. (2012), predominantly ginger producing countries include India, China, Sierra Leone, Australia, Fiji, Indonesia, Nigeria, Bangladesh, Jamaica, and Nepal. India stands as the largest global producer of ginger, contributing approximately one-third of the world's total production (Kumar *et al.,* 2014). India is a leader in term of area and production of Ginger. In India, during 2023-2024 ginger production was 2503 thousand metric tons with an area of 210 thousand hectare. Major ginger producing states are Madhya Pradesh, Rajasthan, Gujarat, Karnataka, Telangana, Andhra Pradesh, Maharashtra, Orissa, Assam, Uttar Pradesh, West Bengal, and Kerala (Anonymous, 2024).

Ginger holds significant economic and cultural importance in Karnataka, particularly in the hilly Malenadu region encompassing Shimoga, Kodagu, Chikkamagaluru, North canara and parts of Mysuru as well as Bidar and Haveri. Karnataka ranks among India's leading ginger-producing states, contributing substantially to national spice output. Favourable agro-climatic conditions, rich lateritic soils, adequate monsoon rainfall, and moderate temperatures have traditionally supported high yields and good-quality rhizomes (Mahesha *et al*., 2020).

In Karnataka, ginger is planted in the month of May-June as rainfed crop immediately after the pre-monsoon showers. It starts sprouting in June and tillering continues until in the late in the season. High soil moisture and optimum temperature (25-30^{0}C) prevailing throughout the growing season. Moreover, young tissues of the host which *Pythium* prefers to infect are also readily available and the pathogen spreads though soil water by means of zoospores, hyphal fragments and infected planting materials. The pathogen associated with rhizome rot complex disease of ginger in Karnataka includes *Pythium aphanidermatum* (soft rot), *Ralstonia solanacearum* (bacterial wilt), *Fusarium solani* (yellows), *Sclerotium rolfsii* (Sclerotium rot) and *Meloidogyne incognita* (root knot).

Due to variation in weather conditions *viz*.,relative humidity (90-95%), night temperature (15-22□), morning dew, cloudy weather, less plant spacing, high and drizzling rainfall, rainfall with intermittent sunshine as well as high dose application of nitrogenous fertilizers leads to develop epidemics of new foliar disease complex in ginger (*Xanthomonas* leaf blight, *Proxipyricularia* blast and *Colletotrichum* leaf spot) in Shivamogga and other ginger growing districts of Karnataka, Because of severity of foliar disease complex roving survey was conducted during 2025 June and July in seven talukas of Shivamogga district where ginger is grown widely by the farmers. Further, characterized the pathogens and confirmed their pathogenicity.

MATERIALS AND METHODS

A roving intensive survey was conducted from June - July 2025 to know the incidence of epidemics of ginger foliar disease complex (*Xanthomonas* leaf blight, *Proxipyricularia* blast and *Colletotrichum* leaf spot). During survey 66 ginger fields in 59 villages were covered in seven talukas of Shivamogga district *viz*., Shivamogga, Sagar, Soraba, Bhadravathi, Hosanagara, Thirthahalli and Shikaripura of Karnataka state. The survey was conducted by Zonal Agricultural Horticulture Research Station, Navile, Keladi Shivappa Nayaka University of Agricultural and Horticultural Sciences, Shivamogga.

Table 1. Severity of foliar diseases of ginger in Shivamogga district during June to July 2025.

Taluk	**Village**	**Severity of foliar diseases caused by**		
		***Xanthomonas* sp.**	***Proxipyricularia* sp.**	***Colletotrichum* sp.**
Bhadravathi	Anaveri	+++	+++	+
	Antaragange	++	++	+
	Arabillachi	+++	++	+
	Kaimara	++	+++	+
	Holaluru	+++	++	+
	Balekatte	++	+++	+
	Devarahalli	+	++	+
	Holehonnuru	++	+	++
Hosanagara	Hosanagara	++++	++++	+
	Nitturu	++++	++++	+
Sagar	Gowthampura	++++	+++	+
	Gowthampura	+++	+++	++
	Hosanahalli	++++	+++	+
	Iruvakki	+++	+++	++
	Kannuru	++++	+++	+
	Kannuru	+++	+++	+
	Narasipura	++++	++	++
	Shuntikoppa	+++	+++	+

	Siddapura	++++	++	+
	Thangalwadi	++++	+++	++
Shikaripura	Anavatti	+++	+++	+
	Anavatti	+++	+++	++
	Anavtti	++	+++	+
	Anjanapura	++	+++	+
	Hosuru	+++	++	+
	Isssuru	++	+++	+
	Issuru	++	++	+
	Kalmane	++	++	+
	Kaniya	++	++	+
	Kaniya	++	+++	+
	Narasapura	+++	++	+
	Shettihalli	++	+++	+
	Shiralakoppa	++	++	++
	Shiralakoppa	+++	++	+
	Shiralakoppa	+++	+++	+
	Shivaji kaniya	++	+++	+
	Shivaji kaniya	++	++	+
	Thogarsi	++	++	+
	Udugani	++	++	+
Shivamogga	Abbalagere	++	++	+
	Agasavalli	++	++	+
	Ayanuru	++	++	+
	Basavana ganguru	++	++	+
	Basavapura	++	++	+
	Beeranahalli	++	+++	+
	Bikkona halli	++	+++	+
	Byranakoppa	++	++	+
	Hosalli	++	++	+
	M.Anasavadi	+++	++	+
	Savalanga	++	++	++
Soraba	Arekoppa	++	++	+
	Balekoppa	++	+++	+
	Hale soraba	++	+++	+
	Heggodu	++	++	+

	Hosakoppa	+++	++	+
	Hosalli	++	++	++
	Kumsi	++	+++	+
	Kuppe	++	+++	++
	Kuppe gudda	++	+++	+
	Kuppegudda	++	++	++
	Ulavi	++	++	+
Thirthahalli	Alase	++	++	+
	Araga	++	++	+
	Balehalli	++	++	+
	Kavaledurga	+++	++	+
	Umblebaylu	++	++	+
	Bejavalli	+++	+++	+

Note: Disease severity

+ Low (up to 5 % leaf area affected); ++ Medium (up to 6 to 20 % leaf area affected) +++ High (up to 21 to 40 % leaf area affected) ++++ Very high (> 40 % leaf area affected)

Based on the *Proxipyricularia* blast (*Proxipyricularia zingiberis*) symptoms explained by Klaubauf *et al*. 2014 and Nguyen Chi Hieu *et al*., 2021 and *Colletotrichum* leaf spot (*Colletotrichum zingiberis*) explained was first reported by Sundararaman (1922) from the Godavari district of Andhra Pradesh and the species *C. zingiberis* was identified by Butler & Bisby (1931) and the Bacterial leaf blight (*Xanthomonas* axanopodis pv. *zingiberis*) were recorded based on water soaked lesions on leaves and stem regions.

During the study, affected ginger leaf and stem regions were systematically examined for the appearance of *Xanthomonas* leaf blight, *Proxipyricularia* blast and *Colletotrichum* leaf spot affected symptoms and their occurrence were recorded visually and converted to severity for individual disease as given in Table 1.

Isolation, morphology, culture and pathogenicity of *Colletotrichum zingiberis* was followed the standard procedure made by Darshana, *et al.,* 2014. Isolation, morphology, culture and pathogenicity of *Proxipyricularia zingiberis* was followed the standard procedure made by Duong Thi Nguyen *et al.,* 2022, Isolation, morphology, culture and pathogenicity of *Xanthomonas axanopodis pv. zingiberis* was followed the standard procedure made by Praveen *et al.,* 20219

RESULTS AND DISCUSSION

During intensive roving survey of ginger foliar disease complex, observed presence of different types of symptomatology in seven talukas of Shivamogga district. From our study we found presence of three types pathogens producing different symptoms *viz*., Bacterial leaf blight caused by *Xanthomonas axanopodis* pv. *zingiberis*, Blast caused by *Proxipyricularia zingiberis* and leaf spot caused by *Colletotrichum zingiberis*.

Bacterial leaf blight

Symptoms produced by *Xanthomonas axanopodis* pv. *zingiberis*

Xanthomonas leaf blight of Ginger

Symptoms: Small, irregular water soaked lesions on leaves of ginger both on upper and lower surfaces. Under favorable weather conditions the water soaked lesions enlarges and completely covered the foliage of ginger and caused blighted or burnt appearance in field conditions (Fig. 1a). The bacterial pathogen was confirmed under laboratory conditions by ooze test (Fig. 1b), Grams stain test (Plate 1c) and 3% KOH test (Fig. 1d), Isolation and purification from leaf tissues on nutrient agar (Fig. 1e) and proving the Koch’s postulates (Fig. 1f).

Small irregular water soaked lesions on leaves of ginger. Under favorable climatic conditions the water soaked lesions enlarges and completely covered the foliage of ginger and causes blighted or burnt appearance in field conditions and also observed the water soaked lesions stem regions just above the soil region (Fig. 1a). Though, conducted Bacterial ooze test to confirmation and after few minutes white milky opaque exudation came out from water soaked lesions of ginger leaf and stem regions (Fig. 1b) and the symptoms of *Xanthomonas axanopodis* pv. *zingiberis* leaf blight is first report from India and world.

Cultural, morphological, biochemical and Gram stain characters of *Xanthomonas axanopodis* pv. *zingiberis*

We observed Yellow mucoid colonies on Nutrient agar after 36 hours of isolation (Fig. 2c), The isolated bacterial pathogen tested with three Percent potassium hydroxide (3% KOH) biochemical test and gave string or thread like structure (Fig. 1d). Apart from this, bacterial culture shows pink colour to gram stain reaction (Fig. 2e). Further, also proved Koch's postulates to test bacterial culture (Fig. 2f), after fourth day small water soaked lesion appeared on leaves of ginger (Fig. 2g).

a. Development of water soaked lesion

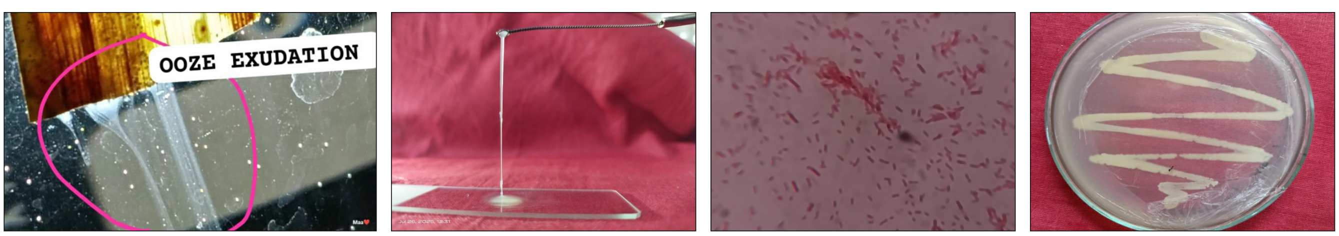
b. Foliage covered with water soaked lesions

c. Water soaked lesions on stem

d. Blighted appearance

e. Severely affected ginger leaves

Fig. 1. *Xanthomonas axanopodis* pv. *Zingiberis* leaf blight symptoms of Ginger



a. Bacterial ooze test

b. 3% KOH test – showing string/thread like

c. Grams staining – Red color (G-ve)

d. *Xanthomonas* culture on Nutrient Agar

Fig. 2. Xanthomonas axanopodis pv. Zingiberis laboratory study

Results of survey of seven talukas of Shivamogga district presented in Table 1 and Fig. 2. *Xanthomonas axanopodis* pv. *zingiberis* leaf blight present in all the 82 surveyed villages from moderate to severe form and enhancing the disease severity in short period of time under favorable weather conditions. All seven talukas *viz*., Shivamogga, Sagar, Soraba, Bhadravathi, Hosanagara, Thirthahalli and Shikaripura prone to more severity of bacterial pathogen.

Symptoms produced by *Proxipyricularia zingiberis*

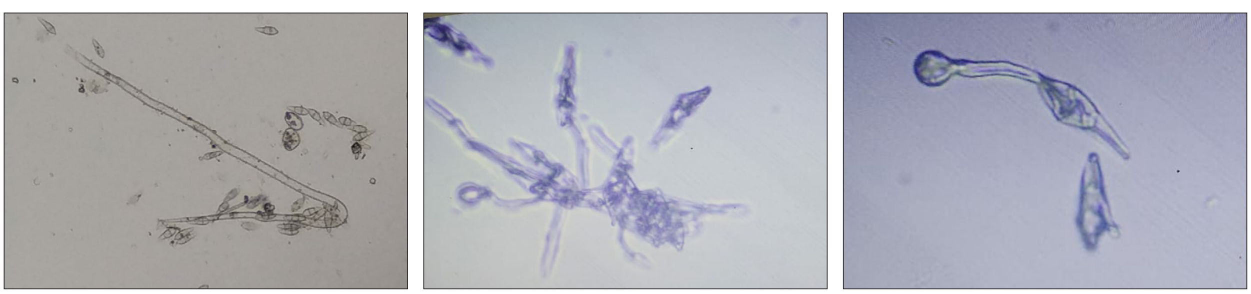
Proxipyricularia blast

On the ginger leaf and stem regions observed small black or olive green spots initially and under favorable weather conditions spots converted into diamond or spindle shape and also observed small sclerotial bodies later the spots coalesce and causes blast or drying of the foliage (Fig. 3a). *Proxipyricularia* fungal pathogen was confirmed by isolation on Potato Dextrose Agar and purification by hyphal tip method on 2% agar (Fig. 3b), Sectioning of diamond/spindle shape leaf tissues and observed pyriform conidia with conidiophore (Fig. 3c) and proved Koch's postulates (Fig. 3d).

On the ginger leaf and stem regions observed small black or olive green spots initially and under favourable weather conditions, spots converted into diamond or spindle shape and also observed small sclerotial bodies afterwards the spots coalesce and causes blast or drying of the foliage (Fig. 3a) and from our study the symptoms of *Proxipyricularia zingiberis* blast is first report from India.

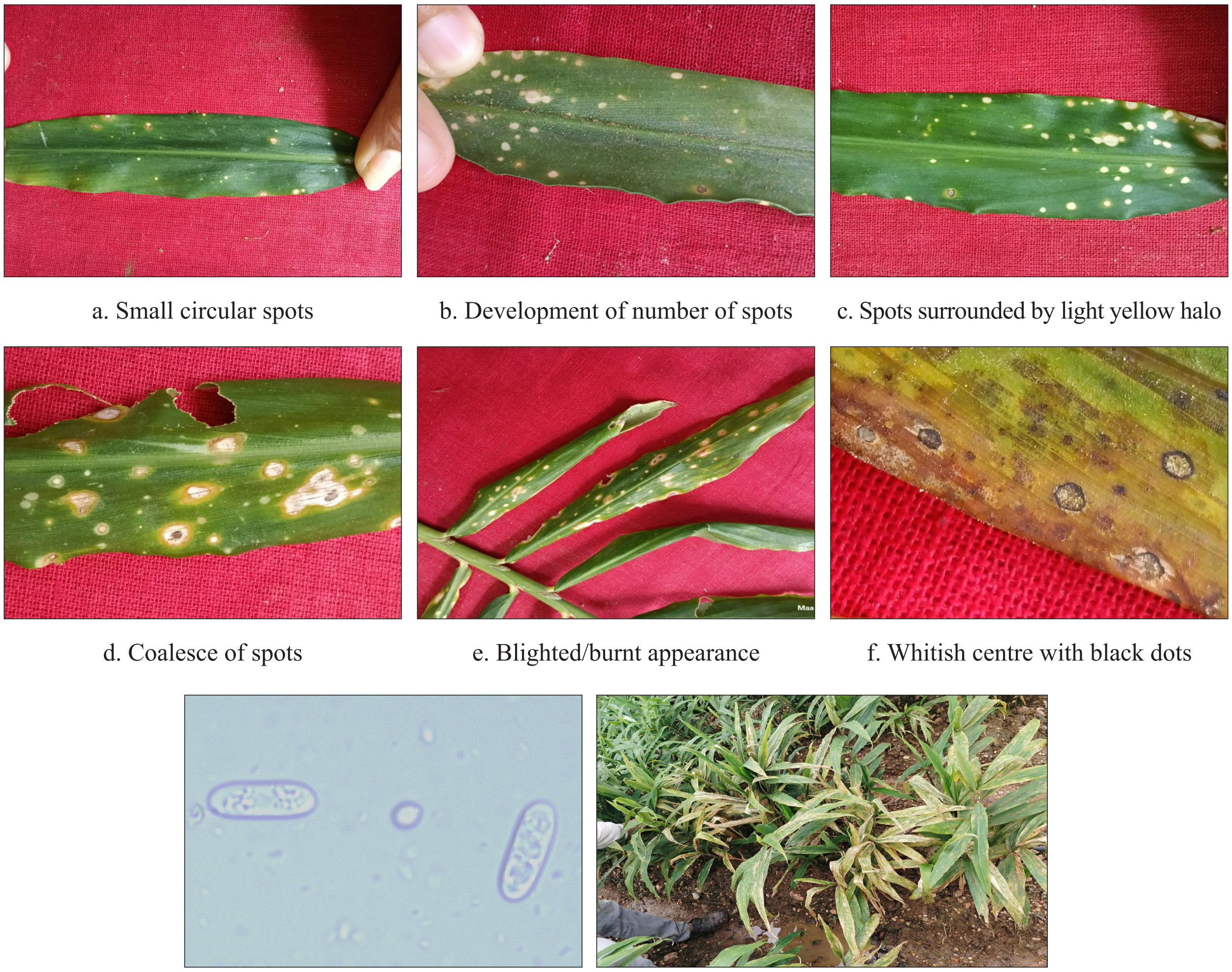
a. Development of number of spots | b. Diamond shape/ Spindle shape spots | c. Blighted appearance on ginger stem | d. Severely affected ginger plant

e. Blighted/burnt appearance | f. Severely affected field view | g. Pyriform conidia



h. Conidia with conidiophore | i. Mycelium development from conidia | k. Germinating conidia

Fig. 3. *Proxipyricularia zingiberis* Blast symptoms of Ginger



a. Small circular spots
b. Development of number of spots
c. Spots surrounded by light yellow halo
d. Coalesce of spots
e. Blighted/burnt appearance
f. Whitish centre with black dots
g. Hyaline conidia
h. Severely affected field view

Fig. 4. *Colletotrichum zingiberis* leaf spot symptoms and of Ginger

Cultural and Morphological characters of *Proxipyricularia zingiberis*

Initially whitish mycelia mat growth observed on Potato Dextrose Agar, after utilisation of carbon source the pathogen converted into black mycelia. By blast affected ginger leaf tissue sectioning observed two septate (3 celled) pyriform conidia and septate mycelium (Fig. 2b).

Results of survey of seven talukas of Shivamogga district presented in Table 1 and Fig. 2. *Proxipyricularia zingiberis* blast presented in all the 82 surveyed villages from moderate to severe form and enhancing the disease severity in short period of time under favourable weather conditions. All seven talukas *viz*., Shivamogga, Sagar, Soraba, Bhadravathi, Hosanagara, Thirthahalli and Shikaripura prone to more severity of blast pathogen. The present study was agreement with Nishikado 1917 and Kato *et al*. 2000 ICAR- IISR report in Kodagu district of Karnataka (*Anon*. 2025). *Proxipyricularia zingiberis* is phylogenetically distant from *Pyricularia* although morphologically, it appears similar, with medium brown conidiophores and a terminal and intercalary denticulate rachis, and subhyaline, 2-septate, obclavate conidia. Isolates of *P. zingiberis* from *Zingiber mioga* and *Z. officinale* are able to infect plants, but not *Oryza*, *Setaria* or *Panicum* spp. Nishikado (1917) regarded the fungus from Zingiber as genetically distant from *Pyricularia* species isolated from rice or other Poaceae, as well as (Kato *et al*. 2000) using RFLP patterns and (Hirata *et al*. 2007) using multilocus sequence analysis.

Symptoms produced by *Colletotrichum zingiberis*

***Colletotrichum* leaf spot**

On the ginger leaf observed small spots initially and later the spots surrounded by light yellow halo and cover the foliage of ginger (Fig. 4a). *Colletotrichum* fungal pathogen confirmed by isolation on Potato Dextrose

Agar and purification by hyphal tip method on 2% agar (Fig. 4b), sectioning of leaf spot tissues and observed hyaline single celled conidia with oil globules (Fig. 4c) and proved Koch's postulates (Fig. 4d).

On the ginger leaf observed small spots initially and later the spots surrounded by light yellow halo and cover the foliage of ginger (Fig. 4a). While, according to Sundararaman (1922), Colletotrichum leaf spot in India was characterized with small round to oval, light yellow spots on leaves and leaf sheaths, which gradually increase in size and coalesce to form large discoloured areas. The infected areas often dry up at the center, forming shot holes. However, the symptoms observed in the present investigation were in agreement with the earlier reports. Colletotrichum leaf spot was first reported by Sundararaman (1922) from the Godavari district of Andhra Pradesh and the species *C. zingiberis* was identified by Butler & Bisby (1931).

Cultural and Morphological characters of *Colletotrichum zingiberis*

Colletotrichum zingiberis produce whitish mycelium afterwards brown ash color on Potato Dextrose Agar (Fig. 3b), by sectioning of leaf spot tissues and observed dumble shaped conidia with oil globules (Fig. 3c). Results of survey of seven talukas of Shivamogga district presented in Table 1 and Fig. 4. *Colletotrichum zingiberis* leaf spot present in all the 82 surveyed villages from low to moderate form. All seven talukas *viz*., Shivamogga, Sagar, Soraba, Bhadravathi, Hosanagara, Thirthahalli and Shikaripura *Colletotrichum zingiberis* leaf spot is present. The present investigation was agreement with Darshana *et al*. 2014, Colour of the colony varied from white to dull grey and considerable variation was observed in the growth rate of the isolates. The conidial shapes varied with regions and were cylindrical with tapering ends, cylindrical, elliptical or dumbbell, whereas.

CONCLUSION

Intensive roving survey was conducted on epidemics of ginger foliar disease complex in seven talukas *viz*., Shivamogga, Sagar, Soraba, Bhadravathi, Hosanagara, Thirthahalli and Shikaripura of Shivamogga district in 82 farmer fields to know the severity. From this study we identified three diseases *viz*., *Proxipyricularia zingiberis* blast is first report from India and *Xanthomonas axanopodis* pv. *zingiberis* leaf blight is first report from India and world as well as *Colletotrichum zingiberis* leaf spot

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MS Received: 03 May 2025
MS Acceptance: 07 June 2025

Pest Management in Horticultural Ecosystems
Vol. 31, No.1 pp 94-96 (2025)
DOI Number : 10.5958/0974-4541.2025.00013.9

RESEARCH NOTE

New record of infestation of Malabar Parakeet [*Psittacula columboides* (Vigors, 1830)] on small cardamom

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ABSTRACT: A large-scale infestation of the Malabar parakeet, *Psittacula columboides* (Vigors, 1830), is reported on small cardamom [*Elettaria cardamomum* (L.) Maton; *Zingiberaceae*] for the first time. Nearly one hundred hectares of cardamom area was infested by *P. columboides,* and more than seventy-five farmers were affected in the Cardamom Hill Reserve area, Idukki district, Kerala, India. The bird has been causing damage to the economic part of the plant (capsule) by scooping the fruit surface with its beak and feeding on the internal content. Ground-level feeding and considerable damage to the cardamom capsules by *P. columboides* were unusual and unexpected. The possible reasons for the massive occurrence of this bird species and strategies to manage it in this unique agro-ecosystem were discussed.

Keywords: Cardamom Hill Reserves, *massive occurrence, parakeets, damage*

Small cardamom [*Elettaria cardamomum* (L.) Maton; Zingiberaceae], a native of the moist evergreen forests of the Western Ghats of southern India, is widely cultivated for its spicy aromatic capsules in the Indian Cardamom Hills (Ravindran, 2002). India is the second-largest producer, and the Cardamom Hill Reserves (CHR) in Kerala contributes nearly 90% of India's cardamom production (Spice Board, 2024). The CHR, a part of the southern Western Ghats, is a tropical high-upland, mid-elevation evergreen forest surrounded by the Periyar Tiger Reserves, Kannandevan Hills and Thodupuzha Ranges (Pascal *et al*., 2004; Murugan *et al*., 2006). Bio-geographical peculiarities of the growing area as well as high-value nature of the crop make the cardamom agro-ecosystem unique and pest-intensive in nature (Nafeesa *et al*., 2024). Both vertebrate and invertebrate pest species are causing considerable threat to the cardamom crop (Chakravarthy and Srihari, 2000; Gopakumar and Chandrasekar, 2002). There are over sixty-seven invertebrate (Gopakumar and Chandrasekar, 2002; Joshi *et al*., 2023) and twelve vertebrate (Chakravarthy and Srihari, 2000) pest species known to cause damage to cardamom crops.

The blue-winged parakeet, or Malabar parakeet (*Psittacula columboides*), is a species of parakeet resident to the Western Ghats, and they are mainly found in upland (most abundant in the hills between 1500 and 3500 ft. msl) evergreen rainforest but also in deciduous forest with bamboo and abandoned coffee and rubber fields (Juniper and Parr, 2010; Grimmett *et al*., 2014). The diet of *P. columboides* is mainly grains and fruits, especially wild figs; also, flower petals and nectar (Salim Ali, 2002). The species has been assessed for the IUCN Red List of Threatened Species and has been listed as "Least Concern" (IUCN RED LIST, 2024). Avian species, *viz*., red spur fowl (*Galloperdix spadicea* G.), red jungle fowl (*Gallus* spp.) and grey jungle fowl (*Gallus sonneratii* T.) were already reported to be feeding on cardamom capsules (Chakravarthy and Srihari, 2000). The infestation of *P. columboides* and the nature of damage on small cardamom reported here is a new record.

Information on the massive infestation of parrots on cardamom crops was received from the 'Mavadi' area of the Nedumkandam block in Idukki District, Kerala, India, during the 2nd week of September 2024. Scientists from the Cardamom Research Station, Kerala Agricultural University, Pampadumpara, confirmed the information on inspecting the farmers' fields (9.869997N, 77.117054E; 9.871296N, 77.113184E; 9.882161N, 77.120291E) of the locality. The harvests were not even started by the farmers in the study fields due to severe labor shortages. The extent of infestation, bird species involved, and feeding nature on the crop were recorded. The indigenous and other techniques followed by the farmers to scare the birds were also noted. The extent of infestation was assessed based on regular and continuous field inspections and inquiries with the farmers for a period of two weeks. As the birds were very swift in flying and timid to even mild sounds, the nature of damage was studied by noting the infected panicles and fed capsules. Preference level of the mature and immature capsules and mode of attack were also recorded. For the purpose of species identification, bird photographs taken from the fields were matched with the slides and descriptions given in books (Juniper and Parr, 2010; Grimmett *et al*., 2014). Farmers feared the bird groups as migratory birds. But the authors suspected it was groups of Malabar parakeets, and to confirm the identity, the photographs were sent to experts involved in the bird biodiversity studies of the Western Ghats.

As per the field visits and the primary information collected from the farmers, nearly one hundred hectares of cardamom area was infested by the birds, and more than seventy-five farmers were affected. A similar type of infestation was also reported from another area (Udumbanchola) in Idukki district, Kerala, during subsequent periods. During the initial field inspection on the 11 September 2024, many of the shade trees in the infested area had three to five parakeets on the top, and the surrounding area was also filled with the call of birds. The bird has been causing damage to the economic part of the plant (capsule) by scooping the fruit surface (Fig. 1) with its beak and feeding on the internal content (Fig. 2). Fed capsules, along with their wastes, were scattered at the base of the cardamom clumps (Fig. 3). The birds prefer feeding on green and tender capsules to fully ripened capsules. The morphology of the avian species causing damage to the cardamom capsules (Fig. 4) matching with the morphology of the Malabar parakeet (Juniper and Parr, 2010; Grimmett *et al*., 2014).

As *P. columboides* mostly prefer an arboreal type of feeding habit, ground-level feeding and considerable damage to the cardamom capsules were unusual and unexpected. Crackers, beating drums, and making sounds of different predatory animals were practiced by the farmers to scare the birds. Rat (*Bandicota bengalensis* B.), squirrel (*Funambulus palmarum* L.), wild boar (*Sus scrofa* W.), and monkey (*Macaca radiata* L.) were considered the major vertebrate pest species that severely damage cardamom (Chakravarthy and Srihari, 2000). Even though some avian species were reported in cardamom as pests, this is the first record of a parrot species causing considerable damage to the cardamom crop in a large area.

The CHR system is highly fragile and unique in nature. Due to intensive monocrop farming, the complex tropical forest has been converted to a more open, simple, and uniform system (Murugan *et al*., 2009). A clear and drastic shift in the diversity and endemism of tree species can be easily seen in the CHR system (Pascal *et al*., 2004; Salish *et al*., 2015). Deliberate inclusion of preferred tree species and selective tree felling further drop down the diversity (Murugan *et al*., 2022; Nafeesa and Murugan, 2023). Excessive shade lopping reduced the natural regeneration, flowering, and fruit setting in the above-ground tree canopy. Even in August and September months, flowers and small fruits accessibility to arboreal animals were limited in the cardamom hotspots of the CHR area. Unavailability of natural and wild food sources in the infested area may be one of the reasons to trigger the acceptance of cardamom capsules as a new food option for Malabar parakeets. The upper canopy of severely lopped cardamom forest couldn't perform its minimum ecosystem functions (goods and services).

To reduce further damage, nonlethal scaring and botanical deterrence have been advocated to farmers as short-term options. But in this highly sensitive CHR system, understanding the actual root cause and long-term corrective measures in terms of its forest diversity and its roughness can only sustain the production system. As the species involved in this damage is an IUCN Red

Figs. 1 – 4. Infestation pattern of parakeet on cardamom (1, scoops on the fruit surface 2, Damaged capsules 3, Fed capsules at the base of the cardamom clumps 4, *P. columboides* feeding on cardamom)

Listed species as "Least Concern" and the crop is high value in nature, the adoptable measures should not cause any negative impact on the biodiversity as well as the endemic life of the bird species. Finally, we could see a considerable reduction in the parakeet population as well as other wildlife populations upon our follow-up visits. The reason for this reduction in animal biodiversity in the study site is not clear.

ACKNOWLEDGMENTS

The authors are thankful to Dr. K. D. Prathapan, Kerala Agricultural University for his timely involvement in the identification of the bird species. The authors extend their heartfelt gratitude to Dr. Kalesh Sadasivan for confirming the identity of the species. We thank Mr. Mohammad Sulaiman, M., Karimpara, who provided relevant references related to the parrots. The authors thank Mr. Aji Jose, Ilupulikkattu; Mr. Joseph, Maprayil; Mr. Jaimon, Akkattukunnel; Mr. Sabu, Kunnathukattil and Mr. Sunny, Kizhakkel for their support and cooperation throughout the study in the infested area.

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MS Received: 02 May 2025
MS Acceptance: 10 June 2025

Pest Management in Horticultural Ecosystems
Vol. 31, No.1 pp 97-99 (2025)

DOI Number : 10.5958/0974-4541.2025.00010.X

RESEARCH NOTE

First documentation of *Helicoverpa armigera* (Hubner) infestation on vegetative tissues of dragon fruit in Telangana, India

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ABSTRACT: This study presents the first documented case of *Helicoverpa armigera* (Hubner) infestation on the vegetative tissues of dragon fruit (*Selenicereus costaricensis*) in Telangana India. Field surveys conducted across major dragon fruit-growing districts identified larvae feeding on tender stems, leading to visible damage including perforations, wilting, chlorosis, and tissue necrosis. The shift in feeding behavior from reproductive to vegetative tissues highlights the pest's expanding host range and adaptability. These findings have important implications for crop productivity, underscoring the need for the development and implementation of integrated pest management (IPM) strategies to mitigate potential economic losses caused by *H. armigera* and ensure the sustainability of dragon fruit cultivation. Ongoing monitoring and research into pest behavior, as well as the optimization of control measures, are critical to manage this emerging threat.

Keywords: *Helicoverpa armigera*, dragon fruit, *Selenicereus costaricensis*, pest infestation, vegetative tissue damage.

Dragon fruit (*Selenicereus costaricensis* weber; family Cactaceae), also called as Rica night blooming cactus or pitaya or strawberry pear or Kamalam is a fast-growing, climbing cactus species native to Central and South America. Known for its striking appearance, nutritional richness, and commercial potential, it has been recently introduced and commercialized in India. Telangana is one of the key regions for dragon fruit production, with over 250 hectares under cultivation, especially in districts like Sangareddy, Nalgonda, and Rangareddy. The crop's suitability for arid and semi-arid environments, combined with low input requirements and high economic returns, has contributed to its rapid adoption among progressive farmers. Beyond its horticultural promise, dragon fruit is valued for its nutritional benefits, including high levels of antioxidants, vitamin C, dietary fiber, and essential minerals (Anamika *et al.,* 2023). It is used in fresh consumption, beverages, jams, as well as in the nutraceutical and cosmetic industries. Prevalence of pests like ants, nematodes, scale insects, mealy bugs are common in dragon fruit in India. The ants cause major damage to the flowers and fruits. Different fungal (*Gloeosporium agaves, Macssonina agaves, Dothiorella* sp. and *Botryo sphaeriadothidea*), viral (Cactusvirus X), and bacterial (*Xanthomonas* sp. and *Erwinia* sp.) diseases are also reported (Guyen, 1996). This paper reports the occurrence of *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae), a polyphagous pest on vegetative parts of dragon fruit. While traditionally associated with damage to reproductive plant structures, recent reports indicate its emerging role as a pest in fruit crops, including dragon fruit (Sarate *et al.,* 2012; Vinutha *et al.,* 2013; Murua *et al.,* 2014; Safuraie-Parizi *et al.,* 2014; Saraf *et al.,* 2015). However, feeding on vegetative tissues of dragon fruit has not been previously documented, making this the first report from Telangana.

Surveys were conducted from June to September 2023 across dragon fruit plantations located in the districts of Adilabad, Sangareddy, Nalgonda, and Rangareddy in Telangana. A total of 20 fields were randomly surveyed, and symptomatic plants were collected and documented.

Fig. 1. Larva and adult of H. armigera reared from dragon fruit

The collected larvae were reared under controlled laboratory conditions until adult emergence. The emerged moths were identified based on adult morphological characters using standard taxonomic keys (e.g., Matthews, 1999; CABI, 2022), confirming the species as *Helicoverpa armigera* (Hubner). Diagnostic characters such as the forewing pattern, hind wing markings, and overall morphology were consistent with published descriptions. The larvae exhibited cylindrical body, either greenish or brownish in colour, with characteristic longitudinal stripes and black spots, consistent with descriptions by Ali *et al.,* (2009); Queiroz-Santos *et al.,* (2018) and Herald and Tayde (2018). Representative larval and adult specimens were preserved and deposited in the Regional Agricultural Research Station, Adilabad, Telangana.

Feeding symptoms were recorded and photographed. Observations included feeding holes, chlorosis, stem necrosis, wilting, and apical tip collapse. Infestation severity was quantified by assessing the proportion of infested plants and mean larval density per plant across surveyed fields. *H. armigera* larvae were found boring into the tender ridges of dragon fruit stems, producing circular feeding holes 2-5 mm in diameter (Fig.2 and 3). Internal tissue damage resulted in localized chlorosis, wilting, and the collapse of growing tips. In advanced infestations, sap exudation and necrosis of stems were also observed. These symptoms significantly impaired vegetative growth and could potentially reduce overall plant vigor and productivity.

Fig. 2and 3. *Helicoverpa armigera* larval instar scraping the dragon fruit vegetative tissues

The present study reports the first documented occurrence of *H. armigera* (Hubner) infestation on the vegetative parts of dragon fruit in Telangana, India. Field surveys were conducted during the 2024 cropping season across eight major dragon fruit-growing locations, covering 950 plants across Ranga Reddy, Sangareddy, Adilabad, and Nalgonda districts. Infestation was recorded on the stems and young shoots, causing visible boring damage and plant wilting. The extent of infestation varied across locations, ranging from 7.7% to 21.8%, with the highest damage observed in Adilabad, Patancheru (Sangareddy) and Narayankhed. Infestation was observed in 65% of the surveyed fields (n = 20),

Table 1. Extent of damage by H. armigera on dragon fruit in different locations of Telangana

Location (District)	No. of plants observed	No. of infested plants	Damage (%)
Shankarpally (Ranga Reddy)	120	14	11.7
Chevella (Ranga Reddy)	100	18	18.0
Patancheru (Sangareddy)	110	24	8.0
Moinabad (Ranga Reddy)	150	12	8.2
Zaheerabad (Sanga reddy)	130	10	7.7
Adilabad	100	20	20.0
Narayankhed	115	17	14.8
Nalogonda	125	16	12.8

with a mean larval density of 4.2 ± 0.6 larvae per plant (Table 1). The pest was identified through rearing of larvae to the adult stage under laboratory conditions, and confirmed morphologically using standard taxonomic keys. Voucher specimens for both larval and adult stages have been deposited at the Regional Agricultural Research Station, Adilabad. This novel host-pest association highlights the need for continuous pest monitoring and appropriate integrated pest management (IPM) strategies in dragon fruit cultivation.

This report confirms the expanding host range of *H. armigera*, marking the first record of its infestation on vegetative tissues of dragon fruit in Telangana and India. Traditionally recognized for its damage to reproductive parts of crops, the pest's stem-boring behavior in this study highlights a significant shift in feeding ecology. Such infestation not only disrupts vascular tissue but also predisposes plants to secondary infections through larval entry points, as similarly reported in cotton and tomato (Geeta Devi *et al.,* 2024). The multivoltine nature of *H. armigera*, combined with Telangana's favourable climatic conditions, could contribute to year-round pest pressure on dragon fruit. Rising temperatures and changing weather patterns could increase the pest's activity and spread. To address this, immediate surveys and monitoring are essential to assess the full extent of the *H. armigera* infestation. Early detection and timely action will be crucial in preventing further damage from now on. Implementing integrated pest management strategies and ongoing surveillance will help protect dragon fruit production from this growing threat.

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MS Received: 21 April 2025
MS Acceptance: 26 May 2025

Pest Management in Horticultural Ecosystems
Vol. 31, No.1 pp 100-103 (2025)
DOI Number : 10.5958/0974-4541.2025.00005.3

RESEARCH NOTE

Efficacy of insecticides against mango leaf webber, *Orthaga exvinacea* Hampson under laboratory conditions

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ABSTRACT: Laboratory studies were conducted to evaluate the efficacy of insecticides against mango leaf webber, *Orthaga exvinacea* Hampson, at the Post Graduate Research laboratory, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari, Gujarat, India. Six insecticides viz., chlorpyriphos 20 EC, chlorantraniliprole 18.5 SC, chlorfenapyr 10 SC, carbosulfan 25 EC, imidacloprid 17.8 SL, and Azadirachtin 1 EC, were tested against *O. exvinacea*. Among them, the treatment with chlorantraniliprole 18.5 SC showed the highest mortality against *O. exvinacea*, followed by the treatments with chlorpyriphos 20 EC and chlorfenapyr 10 SC. Whereas, azadirachtin 1 EC showed the least mortality. Chlorantraniliprole 18.5 SC was the most effective in controlling *O. exvinacea,* while azadirachtin 1 EC was the least effective.

Keywords: Efficacy, insecticides, mango, *Orthaga exvinacea,* laboratory condition

Mango leaf webber is one of the important pests of mango. Two species *viz.*,, *Orthaga exvinacea* Hampson and *O. euadrusalis* Walker are commonly found on mango in India. In West Bengal, *O. exvinacea* was reported for the first time as a pest of mango. It was originally regarded as a minor pest but now has attained major pest status (Rafeeque and Ranjini, 2011). It is widely distributed in different agro-climatic zones of India and has gained the status of a serious pest in Uttar Pradesh, Uttaranchal, and Andhra Pradesh (Singh *et al.* 2006). It causes about 90 per cent of shoot damage, leading to improper fruit setting (Singh, 1988). The heavily infested trees present a burnt look. It affects the flowers as well as the growth of new flush (Kavitha *et al.* 2005). The early instars scrape the chlorophyll content of the leaves. After that, from the third instar onwards, they start forming the webs by webbing 3 to 4 leaves together initially. As the severity of the pest increases, they move on to the nearby leaves and web them with the older web and start chewing the leaves from inside the web. The larvae are very active in their movement inside the web, where they will have tunnels made up of silken webs to escape and hide. These larvae pupate inside the webbings itself in silken cocoon like case covered with its excreta outside. Severe infestation affects the yield (Verghese, 1998; Reddy *et al.,* 2022). The farmers are largely relying on the use of synthetic chemical insecticides for the management of the insect pests in mango. The broad-spectrum activity of new molecules at low dosages, coupled with low mammalian toxicity and safety to non-target organisms made them an alternative to conventional insecticides (Kumar, 2006). Overuse of non-selective pesticides in agriculture has several adverse effects like pest resurgence and killing natural enemies (Carmo *et al.,* 2010 ; Fernades *et al.,* 2010). To mitigate these problems, new molecules which are relatively safer to non target organisms need to be evaluated for sustainable insect pest management in mango. Keeping these facts in mind, the investigation was undertaken for the evaluation of some new insecticides against *O. exvinacea* Hampson.

An experiment was carried out at the Post Graduate Research laboratory, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari, Gujarat, India under laboratory condition, at 29.46±2.59^{o}C temperature and 38.66±6.52% relative humidity (RH). The experiment was conducted in randomized block design with six treatments; each replicated three times. In the control, only water was treated. The various treatments included chlorpyriphos 20EC (2ml/l water), chlorantraniliprole 18.5SC (0.3ml/l water), chlorfenapyr 10SC (1ml/l water), carbosulfan 25EC (2ml/l water), imidacloprid 17.8SL (0.3ml/l water), and azadirachtin 1EC (2ml/l water). The solution of each insecticide was prepared separately in the glass jars. Fresh leaves of mango plants were plucked and brought to the laboratory and were cleaned with a fine camel hair brush. Five leaves were treated with the solution of each insecticide with the help of continuous atomizer sprayer separately and were allowed to dry for some time and then transferred to Petri dish. For getting second generation, the larvae of *O. exvinacea* were collected from the mango orchard and reared in plastic jar on fresh mango leaves (Fig. 1). After pupation, the pupae were collected and the emerged adults were kept for mating. The identification of male and female was done in the pupal stage by examining the location of genital slit in relation to anal slit with help of stereo binocular microscope. The newly emerged pair of male and female adults were released in separate rearing cages for mating and egg laying. After egg hatching, the larvae were reared under laboratory condition and third instar larvae were collected. Ten third instar larvae were released on treated leaf kept in each treatment (Fig. 2). Two trials were carried out separately at 15 days interval. In both trials, the same number of larvae were released on the leaf before treatment, i.e., the same number of larvae (10) were found before the first spray and second spray. In both the trials, the mortality counts of larvae were taken at 1, 3, 5 and 7 days after spraying.

The data collected were analyzed using analysis of variance (ANOVA) technique following the method described by Panse and Sukhatme (1985). The appropriate standard errors (S.Em. ±) were calculated in each case and the critical difference (C.D.) at 5 per cent level of probability was worked out at the Department of Agricultural Statistics and Computer Science, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari, Gujarat, India. The percentage of co-efficient of variation (CV%) was also worked out for all the cases. The square root transformation of data was done wherever necessary.

The data on the mean number of dead larvae of *O. exvinacea* presented in table 1 showed that there was significant difference among the treatments in the mean number of dead larvae after 1, 3, 5 and 7 days of the first spray. After one day of spraying of insecticides, the maximum mortality was obtained in the treatment of chlorantraniliprole 18.5SC (4.0 larvae) and it was followed by chlorpyriphos 20 EC (3.67 larvae), chlorfenapyr 10SC (3.33 larvae), carbosulfan 25EC (3.0 larvae), and imidacloprid 17.8SL (2.67 larvae). The least mortality of larvae (0 larvae) was observed in the treatment of azadirachtin 1EC and control. A similar trend in the mean number of dead larvae among treatments was observed after three, five, and seven days of the first spray.

Pooled analysis of data over periods after the first spray presented in table 1 indicated that all the treatments were significantly superior to the control. The greatest number of dead larvae was recorded in the treatment of chlorantraniliprole 18.5SC (7.5 larvae), indicating its highest efficiency. It was followed by the treatment of chlorpyriphos 20EC (6.58 larvae), chlorfenapyr 10SC (6.16 larvae), carbosulfan 25EC (5.66 larvae), and imidacloprid 17.8 SL (4.91 larvae). The minimum mortality was obtained in the treatment of azadirachtin 1EC (2.33 larvae) indicating that it was the least effective against *O. exvinacea.*

The data pertaining to the evaluation of different insecticides after the second spray in table 1 showed that there was a significant impact of all insecticides over control. After one day of the second spray of insecticides, the maximum mortality was obtained in the

Fig. 1. Mass rearing of *Orthaga exvinacea*

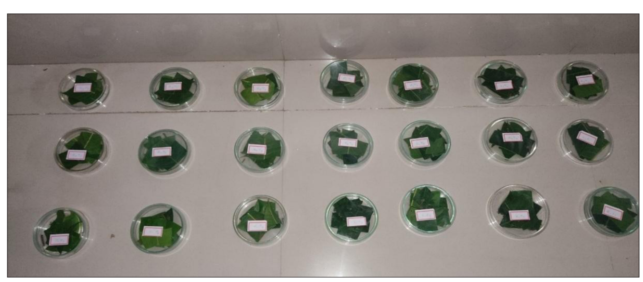

Fig. 2. Experimental set up

Table 1. The mean number of dead larvae of *Orthaga exvinacea* in different insecticidal treatments under laboratory conditions

Treatment (ml/l)	Mean number of dead larvae I Experiment				Mean number of dead larvae II Experiment				Mean mortality		
	1 DAS	3 DAS	5 DAS	7 DAS	1 DAS	3 DAS	5 DAS	7 DAS	First Experiment	Second Experiment	Pooled
Chlorpyriphos 20EC (2.0)	2.04 (3.67)	2.61 (6.33)	2.80 (7.33)	3.08 (9.0)	1.95 (3.33)	2.54 (6.0)	2.73 (7.0)	2.97 (8.33)	2.63 (6.58)	2.55 (6.17)	2.59 (6.38)
Chlorantraniliprole 18.5SC (0.3)	2.12 (4.0)	2.74 (7.0)	3.08 (9.00)	3.24 (10.0)	2.04 (3.67)	2.68 (6.67)	3.03 (8.67)	3.19 (9.67)	2.79 (7.5)	2.73 (7.17)	2.76 (7.33)
Chlorfenapyr 10SC (0.1)	1.95 (3.33)	2.48 (5.67)	2.73 (7.00)	3.02 (8.67)	1.87 (3.0)	2.41 (5.33)	2.67 (6.67)	2.91 (8.0)	2.54 (6.16)	2.47 (5.83)	2.50 (5.99)
Carbosulfan 25EC (2.0)	1.87 (3.00)	2.35 (5.0)	2.61 (6.33)	2.97 (8.33)	1.77 (2.67)	2.27 (4.67)	2.55 (6.0)	2.80 (7.33)	2.45 (5.66)	2.35 (5.25)	2.40 (5.45)
Imidacloprid 17.8SL (0.3)	1.77 (2.67)	2.19 (4.33)	2.41 (5.33)	2.79 (7.33)	1.68 (2.33)	2.20 (4.33)	2.41 (5.33)	2.73 (7.0)	2.29 (4.91)	2.25 (4.74)	2.27 (4.82)
Azadirachtin 1EC (2.0)	0.71 (0.0)	1.22 (1.0)	1.87 (3.0)	2.41 (5.33)	0.71 (0.0)	1.34 (1.33)	1.76 (2.67)	2.34 (5.00)	1.55 (2.33)	1.53 (2.25)	1.54 (2.29)
Control (Water spray)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)	0.71 (0.0)
S. Em. ± (T)	0.06	0.08	0.09	0.07	0.07	0.08	0.10	0.07	0.03	0.04	0.06
CD (T)	0.17	0.25	0.28	0.21	0.21	0.25	0.29	0.22	0.10	0.11	0.17
CV%	6.26	6.89	6.89	4.66	7.71	7.00	7.41	4.90	5.70	4.94	4.58

DAS- Day After Spray, DBS- One Day Before Spray; *Figures in parenthesis are original values whereas those outside parenthesis are square root $\sqrt{(x + 0.5)}$ transformed values.

treatment of chlorantraniliprole 18.5SC (3.67 larvae), which was significantly superior over other treatments. It was followed by chlorpyriphos 20 EC (3.33 larvae), chlorfenapyr 10 SC (3.0 larvae), carbosulfan 25 EC (2.67 larvae) and imidacloprid 17.8 SL (2.33 larvae). The least mortality was obtained in the treatment of azadirachtin 1EC (0.0 larva) and control (0.0 larva). Similar trend in the mean numbers of dead larvae among treatments were observed after three, five, and seven days of the second spray.

Pooled analysis of data over periods after the second spray presented in Table 1 indicated that all the treatments were significantly superior to control. The greatest number of dead larvae was recorded in the treatment of chlorantraniliprole 18.5SC (7.17 larvae), indicating its highest efficiency as compared to others. It was followed by chlorpyriphos 20EC (6.17 larvae), chlorfenapyr 10SC (5.83 larvae), carbosulfan 25EC (5.25 larvae), and imidacloprid 17.8SL (4.74 larvae), which were moderately effective in controlling *O. exvinacea*. The minimum mortality of larvae was obtained in the treatment of azadirachtin 1EC (2.25 larvae), indicating its least efficiency against *O. exvinacea*.

The overall pooled data pertaining to the evaluation of different insecticides after the first and second sprays in Table 1 showed that all the treatments were significantly superior to the control. The significantly greatest number of dead larvae was recorded in the treatment of chlorantraniliprole 18.5SC (7.33 larvae), indicating its highest efficiency as compared to others. It was followed by chlorpyriphos 20EC (6.38 larvae), chlorfenapyr 10SC (5.99 larvae), carbosulfan 25EC (5.45 larvae), and imidacloprid 17.8SL (4.82 larvae), which were moderately effective in controlling *O. exvinacea*. The minimum mortality of larvae was observed in the treatment of azadirachtin 1EC (2.29 larvae), indicating its least efficiency against *O. exvinacea*. These findings are supported by those of Mallikarjun *et al.* (2020) who revealed that chlorantraniliprole 18.5% SC @ 0.2ml/l recorded the least number of active webs per tree

(2.17) and the least number of larvae per web (2.82) as compared to other treatments. Similarly, Murthy *et al.* (2019) observed that chlorantraniliprole 0.03% was the best treatment by reducing 82.41% and 74.60% larvae per web, respectively. Masanori *et al.* (2005) reported the highest efficacy of flubendiamide as a novel insecticide and a very effective chemical against lepidopteran insects. These findings are similar to the present findings.

ACKNOWLEDGEMENT

The authors are highly thankful to the Principal and Head of the Department of Entomology, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari, Gujarat for providing the necessary facilities for conducting the research.

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MS Received: 20 December 2024
MS Acceptance: 14 March 2025

Pest Management in Horticultural Ecosystems
Vol. 31, No.1 pp 104-108 (2025)
DOI Number : 10.5958/0974-4541.2025.00011.6

RESEARCH NOTE

First report of occurrence of leaf beetle, *Madurasia undulatovittata* Motschulsky, (Coleoptera: Chrysomelidae) on Indian bean from Gujarat

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ABSTRACT: A field study was conducted to document the newly reported insect pests of Indian bean, *Madurasia undulatovittata* Motschulsky, (Coleoptera: Chrysomelidae) in South Gujarat during 2024. Infestation of this pest commenced from the seedling stage of the crop coincides 2nd to 4th week of October when plants have 3 to 5 leaves. Infestation was found in sporadic nature. Adults were observed to feed solitary as well as gregariously (2 to 7 adults with average of 4.3 per leaf). Extensive feeding can lead to visible damage from a distance due to the numerous small holes and glistening appearance of the leaves due to chlorophyll scraping. Adults were also scraped the stem of young plants. This is the first report of *M. undulatovittata* infestation on Indian bean from Gujarat.

Keywords: Leaf beetle, *Madurasia undulatovittat,* Indian bean, small holes

Indian beans [*Lablab pupureus* (L.) Sweet is one of the most ancient pulse crops among cultivated pulses. *Lablab* is an Arabic-Egyptin name indicating the dull rattle of the seed inside the dry pod. It is a perennial herbaceous plant that occupies an important place among the fruit and vegetable crops grown in the field as well as in kitchen gardens. It is a multipurpose crop grown for pulse, vegetables and forage. Unlike other leguminous crops, it has also the capacity to fix atmospheric nitrogen in the soil. Dried seeds are a suitable source of protein concentrates. Green seeds and green immature pods are especially used in the preparation of a very famous Gujarati dish named '*Undhiyu'* and in South Gujarat as '*Ubadiyu'*. In Gujarat, the Indian beans is one of the most important vegetable crops grown in the Middle and South Gujarat regions during the *kharif* and *rabi* seasons after the harvest of paddy. In Gujarat, it is one of the important pulse crops widely grown in South Gujarat, particularly in Navsari, Surat and Valsad districts (Shewale *et al.*, 2010).

The high incidence of insect pests in Indian beans is considered the primary biotic constraint to Indian beans in achieving potential productivity and yield instability over the years in South Gujarat. The different pests show vital fluctuations in Indian beans under natural environmental situations. Among various insect pests, *Aphis craccivora* Koch *, Empoasca kerri* Pruthi, *Bemisia tabaci* Gennadius*,* and *Helicoverpa armigera* (Hubner) are potential pests causing considerable damage to Indian beans by attacking various plant parts *viz.,* buds, flowers, fruits and leaves of Indian beans (Adipala *et al.*, 1999). Other minor pests recorded are sap sucking bugs or lablab bug (*Captosoma cribraria* Fab.), leaf miner (*Cosmoptery mimetis* Mey.), pulse beetles (*Callosobruchus* spp.), leaf eating caterpillars, various beetles and weevils, which cause minor losses in crop. This paper is the report of the occurrence of a new Coleopteran insect pest.

During the surveying pests and diseases of mangoes, it was noted that certain farmers who established new mango orchards practice intercropping to generate income. In *rabi* season of 2024, a farmer intercropped Indian bean (variety GNIB-21) in mango orchards of 2 years old. He saw the numerous small circular holes on the leaves. Immediately collected the infested samples and brought to the Agriculture Experimental Station, Navsari Agriculture University, Paria. We examined the leaf samples and also noticed the tiny adults on the underside of the leaves. Observe the specimens using a stereo microscope equipped with the ScopeTek DCM130E microscope-camera and and capture images. Subsequently Preserved the specimens in 70% alcohol and sent them to Dr. K. D. Prathapan, Kerala Agricultural University, Vellayani (India).

Afterward, we arranged a survey to inspect the infested field alongside several other adjacent fields of Indian bean. We observed critically all other life stages of the insects, their behavior, nature and extent of damage

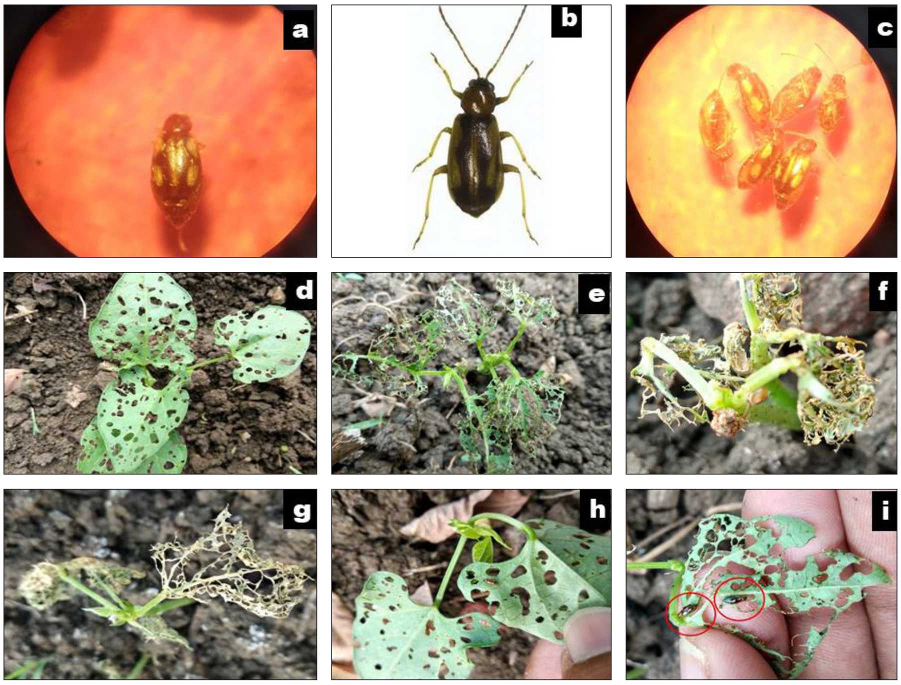

Fig. 1. a, b & c Adults of *M. undulatovittata* (microscopic view); d- nature of damage at initial stage of pest appearance; e,f,g- damaging level at moderate to severe infestation; h,i-adults hiding at lower surface of leaf during day time

caused. To verify the developmental stages of the grub, infested plants were examined by uprooting them and also inspecting the surrounding soil of these plants. The other life stages collected from the fields were brought to the laboratory for further rearing.

In the past, no any records of occurrence and damage by this pest were found on Indian bean from Gujarat, making this the first report. Adults were identified as *Madurasia undulatovittata* Motschulsky (Coleoptera: Chrysomelidae). The adult *M. undulatovittata* beetle is a small, light brown insect that ranges from 2.2 to 3.2 mm in length and 1.1 to 1.3 mm in width (Fig. 1a,b,c). Its head varies from dark brown to light brown, typically appearing darker than the pronotum. The pronotum is generally a pale brown color, usually lighter than the head. The base color of the elytron is lighter than that of the pronotum.

Infestation of this pest commenced from the seedling stage of Indian bean coincides 2^{nd} to 4^{th} week of October when plants have 3 to 5 leaves (Fig.1d). Infestation was found in sporadic nature (Fig.2a) and was not uniform in all the fields. Some fields are free from the infestation. Adults of *M. undulatovittata* are often found on the underside of leaves wherein they feed on foliage primarily during dusk and early morning and makes small circular holes (Fig.1h, i). Adults were observed to feed solitary as well as gregariously (range of 2 to 7 adults with average of 4.3 adults per leaf). Extensive feeding can lead to visible damage from a distance due to the numerous small holes and glistening appearance of the leaves due to chlorophyll scraping (Fig. 1d). Adults were also scraped the stem of young plants (Fig. 2c). In severe cases, this damage can weaken the plant followed by yellowing of plant and reduce its overall vigor (Fig. 2b,e). Only veins are visible in peak incidence (Fig. 1g) and subsequently plants wither and dry (Fig. 1f,g).

Grub stage was not found on leaves. They feeds on root nodules, leading to further losses. Adults were hiding in cracks and crevices of the soil during the daytime. Cent per cent loss was also observed in sporadic condition at early stage of plant when plant has 3-4 leaf stage. In some fields, the plant may not recover, and the crop may need to be resown to achieve a reasonable yield.

The *M. undulatovittata* is widely distributed in Africa (Sudan); Asia (Bangladesh, India [Andhra Pradesh, Bihar, Gujarat, Haryana, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Meghalaya, New Delhi, Orissa, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh, Uttarakhand, West Bengal], Nepal, Sri Lanka, Yemen). Recently revised genus *Madurasia Jacoby* (Coleoptera: Chrysomelidae) and the species *Madurasia obscurella* Jacoby are synonymized with *M. undulatovittata* Motschulsky (Coleoptera: Chrysomelidae) Prathapan (2016).

Gupta and Singh (1984) were the first to document life cycle of *M. undulatovittata* on green gram. They noted that the entire life cycle ranged from 32 to 44 days and that it completes two generations each year. A subsequent, more comprehensive investigation of the life history was conducted by Oza *et al.* (1996) on cowpea. The eggs were deposited individually in the soil near the root zone of the plant. The total life cycle duration, from egg to adult death, ranged from 35 to 48 days for males and 43 to 58 days for females.

Significant damage was noted to foliage, particularly in younger plants wherein larvae reside in the soil and consume root hairs (Srivastava and Singh, 1976; Gupta and Singh, 1981; Satyanarayana *et al.* 1995). Yadav and Yadav (1983) and Faleiro *et al.* (1986) documented its sporadic presence in cowpea. Infestations begin when the plants reach the two-leaf stage, and the insects remain active until the flowering stage (Nayak *et al.* 2005). Ganapathy and Durairaj (1995) identified it as a significant pest affecting black gram and green gram in the drought-prone Pudukottai District of Tamil Nadu. Damage was more pronounced in black gram (9.78%) compared to green gram (1.45%). Sahoo and Patnaik (1994) observed the occurrence of insect pests in both green and black gram, along with their seasonal activity and damage levels in Orissa. The level of damage to black gram, green gram, and cowpea ranged from 20% to 60% (Srivastava and Singh 1976, Swaminathan, 2012). Singh and Gupta (1982) reported the damage to the leaves of green gram and black gram, noting that infestation was more severe in black gram compared to green gram. Gowda and Kaul (1982) documented adult feeding on leaves, buds, and flowers. Additionally, Gowda *et al.* (2006) reported feeding damage by adults on the buds and flowers of pigeon pea.

Mrig and Singh (1985) found that the highest damage occurred on *D. lablab* during the third week of September, with the pest vanishing after the first week of November. Feleiro and Singh (1985) conducted studies on yield and infestation to identify the critical stages of crops that needed protection. They found that infestations during summer led to significant yield losses, whereas pest attacks in the rainy season did not notably affect yield. In summer, Gupta and Singh (1993) documented a peak population of 10.0–10.25 beetles per 10 plants, while in the rainy season, the numbers rose to 29.50–30.25 beetles per 10 plants in green gram. Babu (2017) noted the unusual occurrence of *Madurasia* Jacoby on soybean, black gram and pigeonpea in southern Rajasthan. On an average of 5-6 adult beetles per leaf was recorded on soybean plants and the population was mostly found on the lower side of the leaves.

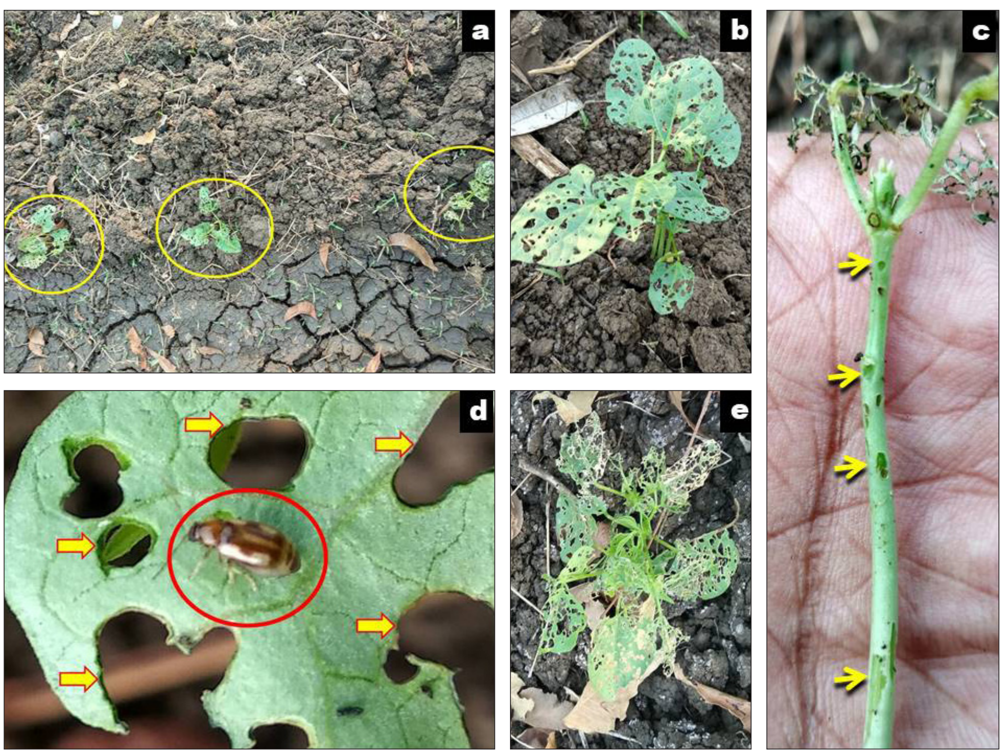

Fig. 2: a-Sporadic infestation by *M. undulatovittata* in severe form; b- yellowing of leaves, c- damage by adults on soft stem; d-Close view of small numerous irregular holes made by adults on leaf; e- Plants lose the vigour, leaves wither and dry

Nayak *et al.* (2004) indicated a significant negative relationship with minimum temperature and humidity during the population growth of black gram. Dhuri *et al.* (1984) noted that the population of *M. undulatovittata* increased under ambient temperatures of approximately 32°C, extended periods of bright sunshine, and high humidity levels along with occasional rainfall. According to Irulandi and Balasubramanian (1999), maximum temperature, minimum temperature, sunshine hours, and wind speed showed a significant negative correlation with damage. The pest infestation on soybean was correlated with high temperature prevailed after continuous dry spell in the zone during 37th Standard week (2nd week of September (Babu, 2017). Sardana and Verma (1986) found a significant negative correlation between the pest population and both maximum temperature and sunshine, whereas rainfall exhibited a significantly positive correlation. The population was not correlated with maximum temperature, humidity, or rainfall, yet it displayed a strong and significant correlation with minimum temperature (Kumar *et al.*, 2007). Pandey *et al.* (1995) found that the pest favored varieties with thicker leaves.

Recently Hadia *et al.* (2023) reported infestation by *M. undulatovittata* on green gram from Anand, Gujarat. Infestation commenced from seedling of green gram i.e., 2nd week of August to 4th week of September. A heavy infestation was also recorded before flowering.

ACKNOWLEDGEMENT: The authors are deeply indebted to the Vice Chancellor, Director of Research and other officers of Navsari Agriculture University (NAU), Navsari for providing the facilities to carry out the work. We are also very much thankful to Dr. K. D. Prathapan, Kerala Agricultural University, Vellayani (India) for identifying the insect.

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MS Received: 24 May 2025
MS Acceptance: 07 June 2025

Pest Management in Horticultural Ecosystems
Vol. 31, No.1 pp 109-111 (2025)

DOI Number : 10.5958/0974-4541.2025.00012.2

RESEARCH NOTE

Bio-efficacy of medicinal leaf powders against drug store beetle, *Stegobium paniceum* Linn. (Coleoptera: Anobiidae) infesting coriander seeds

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ABSTRACT: Bio-efficacy of leaf powders of medicinal plants *viz.*, *Andrographis paniculata* Wall., *Azadiracta indicia* A. Juss., *Eucalyptus globules* Labill. and *Vitex negundo* L. was evaluated for their efficacy against adult drugstore beetle, *Stegobium paniceum* Linn. on coriander seeds under laboratory conditions at Annamalai University, India. Observations were recorded at 12 h interval up to 84 h after treatment. Two percent concentration of all leaf powders showed mortality effect on test insect. *Azadiracta indica* leaf powder 2 % concentration inflicted cent per cent mortality at 84 hours after treatment. This was followed by *A. paniculata* 2 %, *A. indica* 1%, *V. negundo* 2%, *E. globules* 2%, *A. paniculata* 1 %, *E. globules* 1% and *V. negundo* 1%.

Keywords: Drug store beetle, *Stegobium,* leaf powder, mortality

Coriandrum sativum is an annual herb, known for its culinary and medicinal value and cultivated as an important spice crop. Several insects cause damage to coriander seeds under storage conditions. Among them drugstore beetle, *Stegobium paniceum* Linn. (Coleoptera: Anobiidae) is one of the major pests of seeds in storage godowns and gene banks. Its damage also affects the germination of the seed. Botanicals are one of safer means of management of drugstore beetle. Several plants reported with insecticidal, acaricidal, anti-feedent and repellent property in store product pest management (Asawalam *et al*. 2006; Rosman *et al*. 2007; Saravanaraman *et al.* 2020).

Several studies have reported the efficacy of plant powders against storage pests. For instance, powders from *Annona muricata*, *Jatropha curcas*, *Azadirachta indica*, and *Eucalyptus tereticornis* have shown effectiveness against *Sitophilus zeamais* (Asmanizar et al., 2012; Mandudzi & Edziwa, 2016). Similarly, *Azadirachta indica*, *Lantana camara*, and *Tephrosia vogelii* demonstrated anti-feedent activity against *Prostephanus truncatus* (Chebet et al., 2013). Moreover, leaf powders from *Moringa oleifera* and *Allium sativum* have been tested on *Trogoderma granarium*, showing promising results in controlling both adult and larval stages (Musa, 2013).This study aims to evaluate the efficacy of leaf powders in controlling *S. paniceum* in stored coriander seeds.

Coriander seeds infested with *S. paniceum* were collected, and the test insect culture was maintained in 1 kg plastic containers sterilized with ethanol. Each container was filled with 500 g of infestation-free coriander seeds, and 100 pairs of freshly emerged adult male and female *S. paniceum* were released. The containers were covered with muslin cloth and kept at room temperature (28 ± 2ºC). Two containers were maintained as the mother culture throughout the study. Leaves of *Andrographis paniculata*, *Azadirachta indica*, *Eucalyptus globulus*, and *Vitex negundo* were collected, washed, shade-dried for five days, ground, and sieved through a 30-mesh sieve. The resulting leaf powders were stored in airtight containers. For the experiment, 10 g of healthy, disinfested coriander seeds were placed in 9 cm diameter petri plates. Two concentrations of leaf powders (1% and 2% w/w) were mixed thoroughly with the seeds. Each treatment, along with a control, was replicated three times. Twenty freshly emerged *S. paniceum* adults were introduced into each petri plate and covered with muslin cloth to prevent insect escape (Belmain *et al.,* 2001). Mortality was recorded at 12, 24, 36, 48, 60, 72, and 84 hours after treatment. The data were square root-transformed and analyzed using a completely randomized design (CRD).

After 12 h of treatment, the maximum mortality recorded in 2% W/W concentration of *A. paniculata* (6.33 %) followed by 2% W/W concentration of *V. negundo* (5.67 %) and *A. indica* (5.33 %). The same pattern was followed at 24 h after treatment as 2 % *A. paniculata* (8.33%), 2%, *V. negundo* and *A. indica* (7.33%), 2% *E. globules* (6.33%) and 1% *V. negundo* (6.33%). At 48 h after treatment maximum mortality recorded was 2% *A. indica*, (14.67), 2% *A. paniculata* (13.67%), 1% *A.*

Table1. Effect of some medicinal plant powders against *Stegobium paniceum*

Treatment	Concentration (%)	Cumulative mortality (in numbers)							Mortality (%) over control @ 84 HAT
		12 HAT	24 HAT	36 HAT	48 HAT	60 HAT	72 HAT	84 HAT	
Andrographis paniculata	1.0	4.00 (2.22)bc	6.00 (2.62)bc	8.67 (3.10)b	12.00 (3.60)bc	12.67 (3.69)cd	15.67 (4.08)de	18.00 (4.35)ab	**90.00**
Andrographis paniculata	2.0	6.33 (2.70)a	8.33 (3.05)a	12.00 (3.60)a	13.67 (3.82)ab	15.67 (4.08)b	16.67 (4.20)cd	19.67 (4.54)a	**98.35**
Azadiracta indica	1.0	3.67 (2.15)c	6.00 (2.64)bc	7.33 (2.88)bc	12.33 (3.65)bc	15.33 (4.03)b	18.33 (4.39)b	19.33 (4.50)a	**96.65**
Azadiracta indica	2.0	5.33 (2.51)ab	7.33 (2.88)ab	11.33 (3.51)a	14.67 (3.95)a	18.33 (4.39)a	20.00 (4.58)a	20.00 (4.58)a	**100.00**
Eucalyptus globules	1.0	3.67 (2.15)a	5.00 (2.44)c	6.33 (2.70)c	8.33 (3.05)e	12.00 (3.60)d	15.67 (4.08)de	17.33 (4.28)b	**86.65**
Eucalyptus globules	2.0	5.00 (2.44)abc	6.33 (2.70)bc	7.00 (2.82)bc	11.00 (3.46)cd	14.67 (3.95)bc	17.33 (4.27)bc	18.67 (4.43)ab	**93.35**
Vitex negundo	1.0	5.00 (2.44)abc	6.33 (2.70bc	7.00 (2.82)bc	10.00 (3.00)e	12.33 (3.65)d	14.67 (3.95)e	16.67 (4.20)b	**83.35**
Vitex negundo	2.0	5.67 (2.58)ab	7.33 (2.88)ab	7.67 (2.93)bc	10.33 (3.36)d	12.67 (3.69)cd	15.00 (3.99)e	18.67 (4.43)ab	**93.35**
Control	0.0	0.00 (1.00)d	0.00 (1.00)d	0.00 (1.00)d	0.00 (1.00)f	0.00 (1.00)e	0.00 (1.00)f	0.00 (1.00)c	--
SE.d		0.15	0.12	0.15	0.11	0.12	0.08	0.06	
CD (p=0.5)		0.33	0.27	0.34	0.24	0.26	0.18	0.13	

Mean of three replications; Values in parentheses are square root transformed values
In a column means followed by a common letter are not significantly different by DMRT (P=0.05)

indica (12.33%), 1% of *A. paniculata* (12.00%), 2% *E. globules* (11.00%) and 2% *V. negundo* (10.33%). The same pattern followed in 60 hrs after treatment. Data at 72 hrs after treatment were shown the mortality on different treatments 2% *A.indica* caused cent percent mortality (20.00%), 2% *E. globule* (17.33%),1% *A. indica* (18.33%), 2% *A. paniculata* (16.67), 1% *A. paniculata* and 1% *E. globule* (15.67%), 2 and 1 % *V. negundo* viz 15.00% and 14.67% observed. At 84 h after treatment mortality data recorded in the treatments are 2% *A. indica* (20.00%), 2% of *A. paniculata* (19.67%), 1% *A. indica* (19.33%), 2% *E. globules* (18.67%), 2 % *V. negundo* (18.67%), 1% *A. paniculata* (18.00 %), 1% *E. globules* (17.33 %) and 1 % *V. negundo* (16.67 %).

The present indicated that *A. indica* at both 1.0% and 2.0% concentrations was the most effective treatment against derugstore beetle. This is consistent with previous research indicating the high efficacy of neem-based treatments in pest control due to the presence of azadirachtin, a potent insecticidal compound that disrupts pest growth and reproduction (Isman, 2006; Gopalakrishnan et al., 2013).

A. paniculata, another widely used botanical in pest management, also demonstrated significant insecticidal activity, with the 2.0% concentration causing 98.35% mortality. This result aligns with studies showing that Andrographis extracts contain bioactive compounds such as andrographolide, which have shown insecticidal and antifeedant properties (Singh et al., 2014). The slightly lower mortality observed in the 1.0% concentration (90%) suggests that higher concentrations are necessary for maximum efficacy. *E. globulus* and *V. negundo* exhibited moderate insecticidal activity, with both achieving over 80% mortality at their highest concentrations (93.35% and 93.35%, respectively). Previous studies have indicated that essential oils from Eucalyptus contain compounds such as 1,8-cineole and p-cymene, which have shown repellent and toxic effects on various insect pests (Batish *et al.,* 2008). Similarly, *V. negundo* has been shown to possess insecticidal properties, likely due to the presence of alkaloids and flavonoids that interfere with insect metabolism (Mishra *et al*., 2015).

The statistical analysis showed that the efficacy of all botanical treatments was significantly higher compared to the control group (no mortality), where no treatment was applied. The performance of these botanicals supports their potential use in integrated pest management (IPM) systems as eco-friendly alternatives to chemical pesticides. Given the rising concerns about pesticide resistance and environmental sustainability, botanicals like *A. indica* and *A. paniculata* offer promising avenues for sustainable pest control (Isman, 2015; Dubey *et al.,* 2011). Moreover, the time-dependent increase in mortality across the treatments suggests that the bioactive compounds in these leaf powders maintain their efficacy over time, providing a prolonged protective effect. This study confirms that leaf powders, especially *A. indica* and *A. paniculata*, are highly effective in controlling pests when used at appropriate concentrations. The findings support the use of these plants in sustainable pest management programs, offering an environmentally friendly alternative to synthetic pesticides. Future research could explore the synergistic effects of these botanical extracts with other biological control agents to enhance their efficacy and further reduce dependency on chemical inputs.

ACKNOWLEDGMENT

We thank the laboratory, Department of Entomology, Faculty of Agriculture, Annamalai University, Tamil Nadu for the facilities provided.

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MS Received: 18 May 2025
MS Acceptance: 07 June 2025

Pest Management in Horticultural Ecosystems
Vol. 31, No.1 pp 112-115 (2025)
DOI Number : 10.5958/0974-4541.2025.00014.5

RESEARCH NOTE

Insect pest complex on cherry tomato under protected cultivation in Arunachal Pradesh

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ABSTRACT: An experiment was conducted to study the insect pest complex on cherry tomato under protected condition at Pasighat, Arunachal Pradesh, India during summer 2021-22. It was observed that major pests found to damage cherry tomatoes were *Spodoptera litura* (Fab.), *Helicoverpa armigera* (Hb.), *and Liriomyza trifolii* (Burgess). The peak activity *S. litura*, with 2.30 larvae per plant, was recorded from May 6th to 12th (19th SMW). The fruit borer also peaked during this period, with one larva per plant. The leaf miner infestation reached its highest at 21.98% in the second week of May. Correlation between weather parameters and larval population of *S. Litura* was found to be non-significant. It was observed that tobacco cutworm is a potential pest on cherry tomato.

Keywords: Arunachal Pradesh, Cherry tomato, pest complex, protected condition, *Spodoptera litura*

Cherry tomatoes, *Solanum lycopersicum* L. var. *cerasiformae*, are considered the ancestral form (2n=24) of all cultivated tomato varieties. These small fruits come in diverse shapes weighing 10 to 30g and colors, often called "salad tomatoes" due to their rising global popularity. This popularity is attributed to their high content of vitamins A and C, substantial protein levels, flavorful texture and resilience in maintaining firmness even at elevated temperatures (Prema *et al.,* 2011). Cherry tomato production faces many biotic and abiotic stresses, such as seasonal weather which includes temperature, relative humidity, diseases and insect pests. Among the many factors, insect pest infestation is the most important one that affects economically. The major insect pests that cause economic losses in this crop are tomato fruit borer, *Helicoverpa armigera* (Hub.), jassids, *Amrasca biguttula biguttula* Ishida, aphids, *Myzus persicae* Sulzer, mites, *Tetranychus urticae* Koch., leaf miner (*Liriomyza trifolii* (Burgess) and tobacco caterpillar (*Spodoptera litura* F. starting from nursery stage to harvesting stage. These pests considerably impact crop yield and fruit quality, consequently diminishing their market value.

In the recent past, there has been scanty information on the incidence of insect pests and natural enemies in cherry tomato in protected ecosystem. As a result, an insect pest complex study has been initiated to determine the incidence of insect pest complex and study the seasonal incidence of major insect pests on cherry tomato grown under protected condition.

To study the pest complex of major insect pests of cherry tomato, an experiment was conducted on cherry tomato grown in a naturally ventilated polyhouse during 2021-22at the Department of Vegetable Science, College of Horticulture and Forestry, CAU, Pasighat, Arunachal Pradesh. The F_1 hybrid seedlings of cherry tomato were transplanted onto the bed by making holes in the polythene mulch sheet. The experimental area was kept free from insecticidal spray throughout the crop season to record the incidence of insect pests.

To investigate the prevalence of significant insect pests affecting tomatoes, 30 plants were chosen randomly, and their conditions were visually observed weekly during the duration of the growing season. For recording incidence of *S. litura* and *H. armigera*, the number of larvae on 10 randomly selected plants at a weekly interval from the initiation of pest incidence to the final picking of the crop were recorded. The incidence of *L. trifolii* infestation on six leaves (two upper, two middle and two lower) of the plant canopy were observed on 10 randomly selected plants.

The influence of weather parameters such as maximum, minimum temperatures, relative humidity

Table 1. Incidence of insect pests on cherry tomato during different months

Date	SMW*	Number of larvae/plants		*Liriomyza trifolii* infestation (%)
		Spodoptera litura	*Helicoverpa armigera*	
12th - 18th March	11	0.00	0.00	0.00
19th- 25th March	12	0.00	0.00	0.20
26th-31st March	13	0.10	0.00	0.90
1st - 7th April	14	0.20	0.00	2.73
8th-14th April	15	0.30	0.05	7.89
15th-21st April	16	0.90	0.10	11.48
22nd-28th April	17	1.20	0.30	18.90
29th-5th May	18	1.70	0.90	19.50
6th-12th May	19	2.30	1.00	21.98
13th-19th May	20	1.20	0.80	16.40
20th -26th May	21	0.60	0.00	11.20
27th-2nd June	22	0.50	0.00	9.60
3rd-9th June	23	0.00	0.00	0.50

morning and evening time on the population of *S. litura, H. armigera* and *L. trifolii* on cherry tomato plants and the simple correlation coefficient was calculated. For this analysis, weekly meteorological data from the Department of NRM, College of Horticulture and Forestry, CAU (I), Pasighat were utilized. The statistical analysis was performed using Fischer's Analysis of Variance method, as outlined by Panse and Sukhatme (1967), at a 5% level of significance.

During the course of the experiment, which spanned from March 2022 to June 2022, three insect pests *viz.*, tobacco cutworm (*S. litura*), leaf miner (*L. trifolii*) and fruit borer (*H. armigera*), were observed infesting the cherry tomato crop grown under protected conditions as depicted in the table 1. These insect pests were also reported by Cheema *et al*. (2004) under protected condition. Incidence of major pests of cherry tomato observed during the experiment and correlation coefficient of pest population with weather parameters as follows.

***Spodoptera litura* (Fabricius)**

The larval activity of *S. litura* on cherry tomato crop was noticed from the last week of March up to the end of the cropping period. There was an increasing trend in the larval population from the 14th SMW up to the 19th SMW, *i.e.,* 0.2 to 2.30 larvae per plant. The highest number of larvae was observed on the 19th SMW (2.30 larvae/plant). The larval population was decreased from the 20th SMW onwards and reached its status of no observed incidence by the end of the 23rd SMW.These results were similar with earlier findings of Chaudhuri and Senapati (2004) and Dhiman and Singh (2002).

Correlation coefficient between weather parameters and larval population of *S. Litura* showed a non-significant positive correlation with maximum temperature and relative humidity and a negative but non-significant correlation with minimum temperature and relative humidity afternoon, respectively. These results are similar to the findings of Rai *et al.* (2000) and Reddy and Kumar (2005).

***Helicoverpa armigera* (Hubner)**

Observation on the incidence of *H. armigera* was negligible when compared to *S. litura.* Larvae of *H. armigera* initially appeared during 15th SMW with 0.05

Table 2. Correlation coefficient of insect population with weather parameters

Insect pest	Temperature Max (°C)	Temperature Min (°C)	R.H Morning (%)	R.H Afternoon (%)
S. litura	0.103	-0.016	0.039	-0.040
H. armigera	-0.022	-0.105	0.233	-0.028
*L. trifoli*i	0.017	-0.056	-0.048	0.014

larvae per plant and reached its peak incidence during 19th SMW *i.e.,* 1 larva per plant. Several researchers reported that the incidence of *H. armigera* during March, but results were different from these researchers.

With respect to correlation of *H. armigera* larval population with weather parameters it exhibited non-significant and negative relationship with maximum temperature, minimum temperature and relative humidity afternoon, while non-significant positive association with relative humidity morning (Table 3).The obtained results are in line with the findings of Kakati *et al.* (2005).

Liriomyza trifolii **(Burgess)**

The *L. trifolii* was first observed during 2nd SMW causing 0.2 percent leaf infestation and its damage lasted till the end of the cropping period. Peak infestation of 21.98 percent was recorded during 2nd week of May. Thereafter, its incidence was gradually reduced from 3rd week onwards and finally reached to 0.5 percent by the end of 23rd SMW. Present results are similar to the work done by Marcano and Issa (2000), Chaudhuri *et al.* (2001), Asalatha (2002) and Reddy and Kumar (2004).

Perusal of data depicted in Table 4.8 revealed that *L. trifolii* infestation was observed to be positively correlated with temperature maximum temperature and relative humidity afternoon. However, it showed negative association with minimum temperature and relative humidity morning.These results were in accordance with the findings of Asalatha (2002).

The initial infestation of 5 per cent by *S. litura* on cherry tomato started with larval population 0.1 larva per plant in the 13th SMW and reached the maximum of 25 percent during the second week of May *i.e.,*2.3 larvae per plant. It was followed by gradual decrease in the damage with the parallel reduction of larvae (0.5/ plant) and reached only 2 per cent leaf damage due to the end of crop growing period. It can be attributed to non-availability of suitable leaves as food and effect of natural enemies like Braconid parasitoids. Literature pertaining to percent damage level of *S. litura* on cherry tomato under protected condition was scanty to support our research findings.

The findings of this study reveal that *S. litura, H. armigera* and *L. trifolii* were the predominant pests affecting cherry tomatoes cultivated under protected conditions under Arunachal Pradesh conditions.

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MS Received: 14 February 2025
MS Acceptance: 22 April 2025

Pest Management in Horticultural Ecosystems
Vol. 31, No.1 pp 116-118 (2025)
DOI Number : 10.5958/0974-4541.2025.00019.7

RESEARCH NOTE

Efficacy of selected insecticides and botanicals against shoot and fruit borer, *Earias vittella* (Fabricius) on okra

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ABSTRACT: A field experiment was conducted during the *kharif* season of 2024 at Central Research Field, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, India to evaluate the efficacy of eight treatments against *Earias vittella* on okra. The results revealed that all the treatments significantly reduced pest incidence compared to the control. Chlorantraniliprole 18.5% SC was most effective, which recording minimum shoot (10.21%) and fruit (9.98%) infestation, followed by emamectin benzoate 5% SG (11.45% and 12.29%) and spinosad 45% SC (13.86% and 14.11%). Moderate efficacy was observed with Neem oil 5%, *Karanj* oil 5%, *B. bassiana* 5% WP, and *B. thuringiensis* 5% WP. The untreated control showed the highest infestation (24.84% and 25.98%). Maximum yield was obtained with Chlorantraniliprole 18.5% SC (153 q/ha), followed by spinosad 45% SC (150 q/ha). Economic analysis revealed the highest cost-benefit ratio for chlorantraniliprole 18.5% SC (1:6.54), followed by emamectin benzoate 5% SG (1:6.01) and spinosad 45% SC (1:5.54).

Keywords: Botanicals, efficacy, *Earias vittella*, insecticides, okra, yield

Okra (*Abelmoschus esculentus* [L.] Moench) is an annual vegetable of the family Malvaceae, popularly known as ladies' finger or *bhindi*, in India. Often referred to as the "Queen of Vegetables," it is valued for its tender green fruits, which are consumed in various culinary preparations and also possess medicinal properties, including relief from ulcers and haemorrhoids (Kaveri and Kumar, 2020). India is the largest producer of okra, contributing 6,371 million tonnes annually, followed by Nigeria (1,837 million tonnes) and Mali (659 million tonnes). Within India, Gujarat leads production with 1,019.42 thousand tonnes, followed by West Bengal (893.96 thousand tonnes), Bihar (794.10 thousand tonnes), and Uttar Pradesh (349.32 thousand tonnes) (FAO, 2021). Among pests, the okra shoot and fruit borer, *Earias vittella* Fab. is the most destructive, inflicting direct damage to tender shoots and fruits. This pest can cause up to 69% loss in marketable yield, with state-level damage estimates of 22.5% in Uttar Pradesh, 25.93–40.91% in Madhya Pradesh, and 45% in Karnataka, severely affecting both the nutritional quality and market acceptability of the produce (Patil *et al*., 2022).The continuous reliance on systemic insecticides has led to the development of resistance in target pests and disruption of the agro-ecosystem by adversely affecting non-target organisms. Previous research on sustainable pest management in the okra ecosystem has shown that Integrated Pest Management (IPM) approaches, emphasizing the use of biopesticides and other environmentally safe botanicals, have achieved notable success in reducing pest damage, minimizing pesticide usage, and restoring ecological balance. In this context, the present investigation was undertaken to assess the efficacy of both insecticides and botanicals. The aim is to sustainably manage this key pest and maintain its population below the Economic Threshold Level (ETL).

The experiment was conducted during the *kharif* season of 2024 at the Central Research Field, SHUATS, Prayagraj, Uttar Pradesh, India, in a Randomized Block Design with eight treatments replicated three times, using the okra variety 'Arka Anamika' in plots measuring 2 m × 3 m with a spacing of 45 cm × 30 cm, and following the recommended package of practices except for plant protection measures. The soil at the experimental site was well-drained with medium-high fertility. The treatments evaluated against fruit and shoot borer (*Earias vittella*) included *Karanj* oil 5% (0.2 ml/l), emamectin benzoate 5% SG (0.5 ml/l), spinosad 45% SC (0.2 ml/l), chlorantraniliprole 18.5% SC (0.5 ml/l), Neem oil 5% (12.5 ml/l), *Beauveria bassiana* 5% WP

(750 g/l), *Bacillus thuringiensis* 5% WP (5.4 g/l), and an untreated control. Shoot and fruit damage caused by the borer was recorded on five randomly selected plants per plot by noting the total number of shoots/fruits and the number infested in each treatment. Observations were taken one day before spraying and at 3, 7, and 14 days after each spray, and the extent of shoot or fruit damage was expressed as a percentage. After each picking, healthy and infested fruits were counted and weighed separately. The infestation data obtained was pooled and subjected to statistical analysis, and the mean fruit yield per plot was calculated and expressed on a per-hectare basis (Patra *et al*., 2007). The Cost Benefit Ratio (CBR) was calculated by dividing the gross return with total cost of cultivation.

The results (Table 1) after 1st and 2nd spray revealed that all the treatments were significantly superior over the control.

The shoot infestation data of okra recorded at 3, 7, and 14 days after the first spray indicated that all the insecticidal treatments performed significantly better than the untreated control. The lowest shoot borer infestation was observed in plots treated with chlorantraniliprole 18.5% SC (10.21%), followed by emamectin benzoate 5% SG (11.45%), spinosad 45% SC (13.86%), neem oil at 5% (16.94%), and *karanj* oil at 5% (17.83%). Treatments with *Beauveria bassiana* 5% WP (19.25%) and *Bacillus thuringiensis* 5% WP (20.35%) were comparatively less effective but still significantly superior to the untreated control (24.84%).

Fruit infestation data of okra recorded at 3, 7, and 14 days after the second spray showed that all insecticidal treatments were significantly more effective than the untreated control. The minimum fruit borer infestation was recorded in chlorantraniliprole 18.5% SC (9.98%), followed by emamectin benzoate 5% SG (12.29%), spinosad 45% SC (14.11%), Neem oil at 5% (15.87%), and *Karanj* oil at 5% (16.03%). Treatments with *Beauveria bassiana* 5% WP (17.04%) and *Bacillus thuringiensis* 5% WP (18.75%) were comparatively less effective than other treatments but still significantly superior to the untreated control, T0 (25.98%).

The highest yield (153 q/ha) and cost–benefit ratio (1:6.54) were obtained with chlorantraniliprole 18.5%

Table 1. Efficacy of insecticides and botanicals against Fruit and Shoot borer *Earias vittella* (Fabricius) of okra during *kharif* 2024

	Treatment	Fruit and shoot damage (%)									Yield q/ha	C: B Ratio
		1st Spray (Shoot infestation)					2nd Spray (Fruit infestation)					
		1 DBS	3 DAS	7 DAS	14 DAS	Mean	3 DAS	7 DAS	14 DAS	Mean		
T_0	Untreated	20.54	23.00^{a}	25.38^{a}	26.15^{a}	24.84^{a}	24.76^{a}	25.35^{a}	27.66^{a}	25.98^{a}	30.00	1:1.41
T_1	*Karanj* oil @1%	20.56	18.13^{d}	17.62^{bc}	17.76^{cd}	17.83^{cd}	17.27^{c}	14.95^{cd}	15.89^{c}	16.03^{c}	105.0	1:4.83
T_2	Emamactin benzoate 5% SG	16.31	12.16^{f}	10.47^{de}	11.73^{ef}	11.45^{f}	12.93^{e}	11.44^{ef}	12.50^{e}	12.29^{e}	150.0	1:6.01
T_3	Spinosad 45% SC	17.19	15.39^{e}	12.92^{d}	13.27^{e}	13.86^{e}	14.83^{d}	13.49^{de}	14.10^{d}	14.11^{d}	125.0	1:5.54
T_4	Chlorantraniliprole 18.5% SC	16.02	11.0^{f}	9.32^{e}	10.31^{f}	10.21^{f}	10.93^{f}	9.01^{ef}	10.00^{f}	9.98^{f}	153.0	1:6.54
T_5	Neem oil @ 20ml/lit	19.48	17.50^{d}	16.44^{c}	16.88^{d}	16.94^{d}	16.67^{c}	14.26^{cd}	16.70^{c}	15.87^{c}	117.0	1:5.28
T_6	*Beauveria bassiana* 5%WP	20.24	19.74^{c}	18.63^{bc}	19.40^{bc}	19.25^{bc}	18.42^{bc}	16.47^{bc}	16.23^{c}	17.04^{c}	79.0	1:3.56
T_7	*Bacillus thuringiensis* 5%WP	18.21	21.21^{b}	19.32^{b}	20.54^{b}	20.35^{b}	19.43^{b}	17.97^{b}	18.87^{b}	18.75^{b}	70.0	1:3.03
	C.D. (p = 0.05)	NS	1.36	2.79	1.92	1.53	1.82	2.78	1.26	1.41	**-**	**-**
	S. Ed (±)	06.05	01.36	02.79		01.53	01.82	02.78	01.26	01.41	**-**	**-**

DBS =Day Before Spraying, DAS=Day After Spraying, NS=Non Significant, S= Significant

SC, followed by emamectin benzoate 5% SG (150 q /ha; 1:6.01), spinosad 45% SC (125 q /ha; 1:5.54), Neem oil 5% (117 q / ha; 1:5.28), and *Karanj* oil 5% (105 q/ ha; 1:4.83). Treatments with *Beauveria bassiana* 5% WP (79 q/ ha; 1:3.56) and *Bacillus thuringiensis* 5% WP (70 q / ha; 1:3.03) were comparatively less, while the untreated control recorded the lowest yield (30 q/ ha) and cost benefit ratio (1:1.41).

Among the evaluated treatments, chlorantraniliprole 18.5% SC proved to be the most effective in suppressing shoot and fruit borer infestation in okra, recording 10.21% infestation after the first spray and 9.98% after the second spray. These findings are in close agreement with the results reported by (Chandran *et al*., 2020) and (Reddy *et al*., 2019). Emamectin benzoate 5% SG also demonstrated high efficacy, with infestation levels of 11.45% and 12.29% in the first and second sprays, respectively. the observations of (Kaveri and Kumar 2022) and (Rajput and Tayde 2017). Spinosad 45% SC recorded 13.86% infestation in the first spray and 14.11% in the second spray, which is consistent with the findings of (Manikanta and Kumar 2022) and (Dash *et al*., 2020).

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MS Received: 15 April 2025
MS Acceptance: 10 June 2025

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