Journal of Recent Trends in Agriculture and Natural Science
Volume 2, Issue 2, Pages 1-8, 2026 (April-June)
ISSN (online): 3139-1494
DOI: https://doi.org/10.47001/JRTANS/2026.202001
Available Online at https://jrtans.com

Bio-Ecology and Management of Mango Fruit Fly (*Bactroceradorsalis*) Using Eco-Friendly Traps: An Indian Perspective

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Abstract: The oriental fruit fly, Bactroceradorsalis (Hendel) (Diptera: Tephritidae), is one of the most destructive agricultural pests in India, infesting over 600 fruit crop species and causing substantial economic losses in mango production. India, being the world's largest mango producer, faces significant challenges from this pest, with yield losses ranging from 10-40% and severe trade barriers for export of Indian mangoes to other countries. This review synthesizes current scientific knowledge on the bio-ecology of B. dorsalis in the Indian context, including its invasion history, host range, population dynamics, and life cycle, while critically evaluating the efficacy of eco-friendly trapping methods developed and commercialized by Indian research institutions. The ICAR-Indian Institute of Horticultural Research (ICAR-IIHR), Bengaluru, has developed an integrated pest management (IPM) strategy incorporating methyl eugenol-based parapheromone traps, which, when installed at 10 traps per acre along with other IPM practices, can reduce fruit fly infestation by more than 80%. Field studies across India have demonstrated that B. dorsalis is the predominant fruit fly species in many regions, with B. zonata also showing significant abundance, and population dynamics are strongly influenced by weather parameters including temperature, rainfall, and humidity. This review highlights that eco-friendly traps, particularly the ICAR-IIHR fruit fly trap technology licensed to 19 firms generating cumulative revenue of approximately ₹24.12 lakhs between 2009-2024, represent a successful example of public sector research translating into practical field solutions benefiting over 6,000 farmers across multiple states. The technology is widely promoted through government schemes including the Mission for Integrated Development of Horticulture (MIDH) and Rashtriya Krishi Vikas Yojana (RKVY), with state governments including Andhra Pradesh, Karnataka, and Sikkim providing subsidies. This review underscores that sustainable management of B. dorsalis in India requires an integrated approach combining methyl eugenol traps, orchard sanitation, crop hygiene, and biopesticides, supported by strong institutional frameworks and farmer awareness programs.

Keywords: Bactroceradorsalis, oriental fruit fly, eco-friendly traps, integrated pest management, male annihilation technique, methyl eugenol, mango, India.

1. Introduction

India occupies the largest area under mango cultivation globally, and mango (*Mangiferaindica*), popularly known as the 'King of Fruits,' is one of the country's most important horticultural crops, contributing significantly to farmers' livelihoods and export earnings. Despite its wide adaptability and cultivation across almost all states, mango production often faces challenges from insect pests and diseases. Among these, the oriental fruit fly, *Bactroceradorsalis* (Hendel), is recognized as one of the most destructive pests and also a quarantine pest in many importing countries, as its infestation can severely affect fruit quality and restrict international trade of fresh mangoes.

Bactroceradorsalis is the most significant agricultural pest in Southeast Asia and the most destructive pest in India, followed by B. zonata (Saunders) and B. correcta (Bezzi). Genomic studies have revealed that this pest originates from the Southern India region, with three independent invasion and spread routes worldwide: from Northern India to Southeast Asia, China, and Hawaii; and from Southern India toward the African mainland and Madagascar, primarily facilitated by human activities including trade and immigration. This invasive history underscores India's central role in the global distribution of this pest.

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Traditional management of B. dorsalis in India has relied heavily on chemical insecticides, including cover sprays, bait sprays, and fumigants such as Dichlorvos 76% EC. However, with the complete ban on dichlorvos in India from December 2020, farmers and researchers have sought sustainable alternatives. Baits and sprays of conventional insecticides also affect non-target beneficial fauna. Increasing concerns over environmental contamination, non-target effects on beneficial insects, development of insecticide resistance, and stringent food safety regulations have necessitated a shift towards more sustainable, eco-friendly management approaches.

Among the various non-chemical control tactics, eco-friendly traps utilizing behaviour-based attractants have emerged as promising tools for monitoring and managing fruit fly populations. The ICAR-Indian Institute of Horticultural Research (ICAR-IIHR), Bengaluru, has developed an eco-friendly and economically viable Integrated Pest Management (IPM) strategy for effective management of mango fruit fly, with methyl eugenol-based parapheromone traps as a key component. This technology has been widely adopted across major mango-growing states and represents a successful example of translating scientific innovation into practical field solutions.

This review aims to synthesize current scientific understanding of the bio-ecology of B. dorsalis in the Indian context, evaluate the efficacy of eco-friendly trapping methods and other sustainable management strategies, and examine the institutional frameworks supporting their adoption. By examining evidence from field studies across diverse Indian agro-ecological zones, this review seeks to provide a comprehensive framework for sustainable management of this devastating pest in Indian mango production systems.

2. Bio-Ecology, Host Range, and Population Dynamics of Bactroceradorsalis in India

2.1 Host Range and Crop Damage

Bactroceradorsalis is notorious for its exceptionally broad host range, which includes key commercial fruits such as mango, papaya, sapota, guava, pomegranate, citrus, peach, and various other tropical and temperate fruits. The pest's wide host range makes it a significant threat to diverse agricultural systems and increases the difficulty of management through host-specific interventions.

Mango damage occurs when female fruit flies oviposit into ripening fruits using their sharp ovipositor. The eggs hatch into larvae (maggots) that feed on the inner pulp, making the fruit soft, discoloured, and unmarketable. Infested fruits often exhibit characteristic symptoms including premature colour change, soft spots, and premature dropping. In severe infestations, damage can reach up to 90% in some orchards, resulting in substantial economic losses for growers. The presence of fruit fly larvae in harvested fruits also poses a quarantine issue, limiting export opportunities and incurring additional costs for post-harvest treatments.

Research at ICAR-IIHR on the commercial mango variety Banganapalli demonstrated that without management, fruit fly infestation can range from 17% to 66%. Similarly, studies across Indian mango-growing regions have reported yield losses ranging from 10-40%. These losses highlight the urgent need for effective management strategies.

2.2 Species Composition and Diversity in Indian Mango Orchards

Studies across different regions of India have documented the species composition and diversity of fruit flies infesting mango orchards. A comprehensive study in Saharanpur, Uttar Pradesh, during the 2022 mango fruiting season collected fruit fly samples from 12 locations spanning 5 agro-ecological zones using methyl eugenol baited traps. A total of eight species of the genus Bactrocera were found infesting mango orchards in the study region. Out of the total collection from each zone, *Bactrocerazonata* emerged as the predominant species with a total number of 3,750 recorded, followed by *Bactroceradorsali*s (3,022), B. correcta (1,375), and B. tau (1,245). B. tuberculata and B. nigrotibalis exhibited low abundance across all locations.

The diversity indices, as measured by Shannon's index, were highest in Behat, followed by Nakur, suggesting higher diversity in the fruit fly population in these areas. Simpson's reciprocal index also indicated higher values at Behat and Nakur, confirming higher diversity and species richness. This regional variation in species composition has important implications for trap-based management, as different species may respond differently to attractants.

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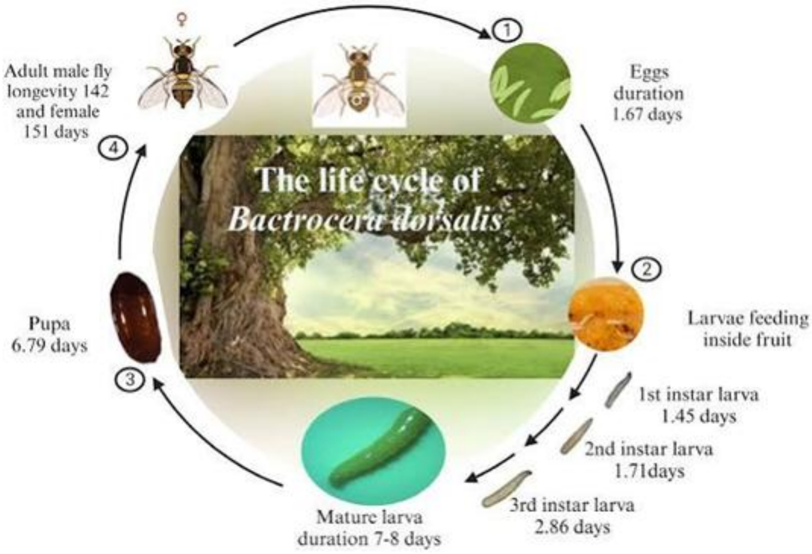

Figure 1: Life Cycle and Biology on Indian Hosts

Studies in Karnataka have documented similar species composition. Research at the Keladi Shivappa Nayaka University of Agriculture and Horticultural Sciences, Shivamogga, during the mango fruiting season from April to May 2022 and 2023, collected three fruit fly species in parapheromone traps: *Bactroceradorsalis* (95.15%), *Bactroceracaryeae* (4.04%), and *Bactroceraversicolor* (0.81%). The predominance of B. dorsalis in these collections underscores the importance of methyl eugenol-based trapping for this species.

2.3 Life Cycle and Biology on Indian Hosts

Understanding the biology of B. dorsalis on Indian host fruits is essential for developing effective management strategies. Research conducted at SVPUA&T Meerut, Uttar Pradesh, documented the morphometric characteristics of B. dorsalis on mango fruit at room temperature. The study revealed that egg length ranged from 0.5 to 0.6 mm (mean 0.53±0.02 mm) and width from 0.1 to 0.3 mm (mean 0.18±0.01 mm). The size of pre-pupae varied from 2 to 3 mm (mean 2.81±0.08 mm) and width from 2 to 4 mm (mean 9.96±0.30 mm). The length of female B. dorsalis varied from 8 to 9 mm (8.69±0.26 mm) and width from 12 to 13 mm (12.59±0.38 mm).

Figure 2: Bactroceradorsalis

The mature 3rd instar larvae become slightly curved, sluggish, and stop feeding, remaining inactive except for metabolic activities. The pupal stage develops within the soil, and adult emergence occurs after completion of the pupal period. The study provides baseline data essential for understanding the pest's biology and developing management interventions targeting vulnerable life stages.

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Figure 3: Oriental fruit fly bactroceradorsalis

Research on alternate hosts has also contributed to understanding the pest's biology. Studies on B. dorsalis on Jamun and Sweet orange revealed that the egg, larval, and pupal periods on Jamun were 1.8±0.78, 7.6±0.51, and 8.9±0.87 days, respectively, while on sweet orange, these periods were 2.9±0.73, 8.7±0.82, and 9.8±0.78 days, respectively. Adult longevity of female flies was greater than that of males. The study also standardized a semi-synthetic larval diet for mass rearing, with banana powder-based diet yielding the highest egg hatchability (82.66±2.51%), pupal recovery (75.32±2.33%), and adult emergence (91.15±3.05%), critical for potential sterile insect technique (SIT) applications.

2.4 Influence of Weather Parameters on Population Dynamics

Weather parameters play a crucial role in the population dynamics of B. dorsalis in Indian mango ecosystems. A long-term field experiment conducted during 2013-16 at Navsari Agricultural University, Gujarat, studied the role of weather parameters on population dynamics of B. dorsalis on mango. Fruit flies were recorded throughout the investigation period, with maximum catches observed during April-July, which coincided with the fruiting and harvesting stages of the crop.

The study identified weather parameters including minimum temperature, evening relative humidity, rainfall, and wind velocity as important predictors of fruit fly catches, while maximum temperature and morning relative humidity failed to establish significant correlation with catches. The optimized model developed using rainfall and wind velocity predicted fruit fly catches with an R^2 value of 78%. This forewarning model may help mango farmers take advance decisions for minimizing quantitative and qualitative crop losses caused by fruit flies.

Research from the Saharanpur study also observed a significant positive correlation between fruit fly population and temperature, while there was a negative correlation with average rainfall and humidity. Similarly, research from ICAR-IIHR on 158 mango genotypes during 2023 and 2024 revealed high fruit fly infestation during May to June (mid-season), with its population density showing a positive correlation with minimum temperature, relative humidity, and morphological fruit traits including fruit weight, length, width, and total soluble solids (TSS). A significant negative correlation was observed with fruit peel thickness.

These findings on weather-population relationships have important implications for timing management interventions. Farmers can use weather-based predictions to schedule trap installation, sanitation activities, and other control measures for maximum effectiveness.

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3. Eco-Friendly Trapping Technologies: Development, Commercialization, and Adoption in India

3.1 ICAR-IIHR Fruit Fly Trap Technology

The ICAR-Indian Institute of Horticultural Research (ICAR-IIHR), Bengaluru, has developed a comprehensive Integrated Pest Management (IPM) strategy for effective management of mango fruit fly, with methyl eugenol-based parapheromone traps as a central component. The technology is based on the 'Male Annihilation Technique' (MAT), which uses a parapheromone called 'methyl eugenol' impregnated into plywood blocks. These blocks are placed in low-cost plastic containers that are hung on mango trees.

The parapheromone attracts a large number of male B. dorsalis and related species, thus reducing the male population in the orchard and surrounding areas. In due course, for want of adequate males, the chances of female flies getting mated are reduced, thus preventing offspring production. Research in Kashmir on various methyl eugenol dispensers demonstrated that the plywood block dispenser captured male flies efficiently for up to 10 weeks. Although the mean number of males captured during the first week was comparatively less than other dispenser types, captures increased during the next 5 weeks. The plywood block was identified as the most attractive and long-lived methyl eugenol dispenser for capturing B. dorsalis, with potential for monitoring and control activities in India.

Recognizing the effectiveness of this technology, ICAR-IIHR facilitated the large-scale dissemination and commercialization of the fruit fly trap technology. Beginning in 2009-10, the technology was licensed to several agro-input companies. Between 2009 and 2024, the technology was licensed 20 times to 19 firms, generating cumulative revenue of about ₹24.12 lakhs. The sustained licensing and adoption highlight the commercial viability and long-term relevance of the technology, demonstrating how public sector research can deliver practical, sustainable solutions benefiting farmers, industry, and the horticulture sector.

3.2 Government Support and Subsidy Schemes

The mango fruit fly trap technology based on methyl eugenol is widely promoted through government support in India. Farmers receive subsidies through schemes such as the Mission for Integrated Development of Horticulture (MIDH) and RashtriyaKrishiVikasYojana (RKVY). Currently, several state governments including Andhra Pradesh, Karnataka, and Sikkim provide subsidies for this technology through their horticulture departments, significantly enhancing large-scale adoption.

The recommended trap density is 10 traps per acre (25 traps per hectare), which should be erected at the onset of fruiting. The technology is simple, very low cost (retail price about ₹40-50/trap with lure), and easy for adaptation by farmers. Under national programmes including the Scheduled Cast Sub Plan (SCSP), Tribal Sub Plan (TSP), Farmer FIRST Programme, RKVY, and MIDH, the technology has been adopted by more than 6,000 mango farmers across several states including Karnataka, Tamil Nadu, Telangana, Andhra Pradesh, Odisha, West Bengal, Punjab, Uttar Pradesh, Chhattisgarh, and Madhya Pradesh.

3.3 Commercial Traps and Products

Several Indian companies have commercialized fruit fly traps based on the ICAR-IIHR technology. Products such as the SK Agrotech Fruit Fly Trap, equipped with a Mac Phll Trap, offer a specialized solution for controlling Bactroceradorsalis infestations in mango, papaya, sapota, guava, pomegranate, and other sweet fruits. These traps are made from high-quality, durable, weather-resistant plastic and are classified as bio/organic with green toxicity rating.

The traps use a targeted pheromone lure to attract and capture fruit flies, significantly reducing their population. Benefits include reduced chemical use, improved crop health, and cost-effective long-term pest management. The availability of commercially produced traps at affordable prices has facilitated widespread adoption among Indian farmers.

3.4 Alternative Insecticides for Traps Following Dichlorvos Ban

The import, manufacture, or formulation of dichlorvos 76% EC was restricted in India from January 2019 and completely

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banned from December 2020. This posed a challenge for trap-based fruit fly management, as dichlorvos was the commonly used fumigant insecticide to impregnate dispensers along with parapheromone for the Male Annihilation Technique.

Research conducted during the mango fruiting season from April to May 2022 and 2023 at the KeladiShivappaNayaka University of Agriculture and Horticultural Sciences, Shivamogga, identified alternatives to dichlorvos. Results indicated that deltamethrin 2.8% EC is the most effective insecticide in parapheromone traps, followed by Malathion 50 EC, which can be used as an alternative to dichlorvos 76% EC to impregnate wood dispensers for trapping fruit flies. This research has ensured the continued effectiveness of trap-based management following the dichlorvos ban.

4. Integrated Pest Management and Sustainable Control Strategies for India

4.1 Pre-Harvest IPM Combining MAT, Sanitation, and Biopesticides

ICAR-IIHR research has standardized a pre-harvest IPM combination of Male Annihilation Technique (using methyl eugenol as a lure) combined with sanitation, which brought down B. dorsalis infestation to 5.00% from an infestation ranging from 17-66% in control plots. The addition of a cover spray of Decamethrin 2.8EC 0.5 ml/l (half the recommended dose) with Azadirachtin (0.03%) 2 ml/l (neem-based botanical) gave 100% control.

This IPM model includes several components:

1. Installation of methyl eugenol traps: Deployment of 20-25 traps per hectare at the onset of fruiting.
2. Crop sanitation: Regular removal and burying of fallen and infested fruits in pits at least 50 cm deep or composting using heat to kill larvae.
3. Bait application: Splashing with 10% jaggery solution mixed with an insecticide on tree trunks.
4. Removal of weed flora: Eliminating plants that serve as resting and sheltering places for fruit flies.

The technology has been demonstrated on more than 60,000 acres in major mango-growing areas and is presently being adapted in almost all major mango-growing belts of the country, resulting in 90-95% reduction in fruit fly infestation.

4.2 Post-Harvest Treatments

Post-harvest treatments play a crucial role in ensuring fruit fly-free mangoes for domestic and export markets. Research at ICAR-IIHR demonstrated that post-harvest treatments with hot water at 48°C for 60 and 75 minutes resulted in 100% control in both time regimes. The untreated fruits, which were also exposed to gravid females but not treated in hot water, showed 30% and 5.5% infestations, respectively, in 2004 and 2005.

This hot water treatment method is especially useful for farmers targeting export markets, where pest-free certification is often required. It avoids the need for chemical fumigation and is completely residue-free.

4.3 Natural and Organic Management Practices

Several organic practices can effectively reduce fruit fly damage without harming the environment: Neem-based organic sprays: Neem plays a crucial role in organic pest management. Neem seed kernel extract or commercially available neem oil-based bioformulations can be sprayed on mango trees during the fruit development stage. These sprays repel fruit flies and interfere with their growth and egg-laying behaviour. Spraying neem every 10 to 15 days, depending on rainfall and fly activity, keeps the orchard safer and is completely eco-friendly.

Fruit bagging: When mango fruits reach the marble size stage, they can be individually covered with paper or cloth bags. This prevents the female fruit fly from reaching the fruit surface to lay eggs. Though labor-intensive, this method is highly effective for farmers growing mangoes for export or high-value markets.

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Field sanitation: Mango farmers should regularly pick up and destroy fallen, infested, or rotting fruits. These fruits may carry maggots or fly eggs. If left on the ground, they become breeding centres for more flies.

4.4 Host Plant Resistance

Research on host plant resistance offers a sustainable, long-term approach to fruit fly management. Screening of 158 mango genotypes was conducted during two successive fruiting years (2023 and 2024) at ICAR-IIHR to assess fruit fly abundance and categorize genotypes from resistant to susceptible.

Among 158 genotypes, the genotypes with no fruit fly infestation grouped in the fourth cluster (Ananthabhata Apple, Appemidi, BalekoppaAppe, DannalliAppe). These genotypes may owe their resistance to their thicker peel with low TSS and smaller fruit size. The study revealed that high fruit fly infestation is governed by multiple factors including fruit availability and prevailing weather parameters, with morphological fruit traits such as fruit weight, length, width, and TSS having limited roles. However, peel thickness was found to significantly influence infestation.

The identification of resistant genotypes provides opportunities for developing mango varieties with inherent resistance to fruit fly infestation, reducing the need for intensive management interventions.

5. Conclusion

This review examined the bio-ecology of Bactroceradorsalis and evaluated eco-friendly management strategies in the Indian context. Key findings reveal that B. dorsalis is the most destructive pest in Indian mango production, causing 10-40% yield losses and severe trade barriers, with B. zonata also showing significant abundance across regions. The ICAR-IIHR methyl eugenol-based trap technology represents a successful public sector innovation, licensed to 19 firms generating ₹24.12 lakhs in revenue (2009-2024) and adopted by over 6,000 farmers, reducing infestation by more than 80%. Government support through MIDH and RKVY schemes, with subsidies from states including Andhra Pradesh, Karnataka, and Sikkim, has facilitated widespread adoption at a retail price of ₹40-50 per trap (10 traps/acre). Weather-based forewarning models using rainfall and wind velocity predict fruit fly catches with 78% accuracy, enabling timely interventions. The integrated pest management combining MAT, sanitation, and biopesticides reduced infestation to 5% from 17-66% in controls, with additional biopesticide sprays achieving 100% control. Resistant genotypes (Ananthabhata Apple, Appemidi, BalekoppaAppe, DannalliAppe) have been identified with thicker peel and lower TSS, offering long-term solutions, while deltamethrin 2.8% EC and Malathion 50 EC have been identified as effective alternatives to dichlorvos following its complete ban in December 2020. Integrating eco-friendly traps with non-chemical tactics offers sustainable management pathways. Future research should validate IPM protocols across agro-ecological zones, develop resistant varieties, and strengthen community-based approaches, while policy must prioritize research funding, subsidy support, and surveillance systems.

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Citation of this Article:

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