International Journal of Agriculture and Plant Science
www.agriculturejournal.in
Online ISSN: 2664-7664
Received: 10-03-2026, Accepted: 10-04-2026, Published: 25-04-2026
Volume 8, Issue 2, 2026, Page No. 64-69

Eco-friendly approaches for the management of tephritid fruit flies

Ankita Singh[1], Sangita Sharma[2*]
[1] Department of Entomology, Dr. YS Parmar University of Horticulture and Forestry, Nauni, Himachal Pradesh, India
[2] Dr. YS Parmar University of Horticulture & Forestry, Regional Horticultural Research and Training Station, Mashobra, Himachal Pradesh, India
Corresponding Author: Sangita Sharma

Abstract
Tephritid fruit flies are of major importance among wide range of insect pests infesting horticultural crops. They exhibit endophagous feeding behavior, which causes both quantitative and qualitative yield reductions. High reproductive potential, broad host range (polyphagy), multivoltine life cycle, protection of maggots within host tissues, high mobility of adults and great climate tolerance challenge their management. As a result, they pose significant threats to global fruit and vegetable production. The pest affects a broad array of fruit and fleshy vegetable crops in tropical and subtropical regions. As a result of intensification of regulatory constraints on insecticides and the rising global demand for safe free food products, there has been a marked shift toward the development of eco-compatible and sustainable strategies for the management of fruit fly populations. The prolonged persistence of chemicals resulted in harmful residue build-up on fruits, raising concerns for both human safety and environmental sustainability, thus highlighting the need for alternative approaches to manage this pest. Different techniques such as behavioral interventions i.e. Sterile Insect Technique (SIT), Male Annihilation Technique (MAT) and quarantine-based measures can play a crucial role in developing a comprehensive fruit fly management program.

Keywords: Fruit flies, polyphagous, biology, damage, pest management, quarantine

Introduction
Fruit flies constitute economically significant pest taxa within the order Diptera and the family Tephritidae, encompassing approximately 4,500 described species distributed across 481 genera. Out of these species, about 5% are found to occur in India. Importance of horticultural crops is manifested by their high export potential, yield and monetary benefits per unit area [1].Several fruit fly species are invasive pests that damage quality fruits in horticultural crops and cause significant value losses. The management of fruit flies is challenging due to their biology, adaptation to various regions and wide range of hosts [2]. Wider adaptability to different zones, highly polyphagous trait, and fast reproductive tendency have led to the emergence of fruit flies as invasive pests of numerous horticultural crops [3, 5].Continuous climatic variability is also contributing to repeated outbreaks of fruit flies in horticultural crops [6-7].Tephritid fruit flies function as quarantine-relevant pests, necessitating stringent phytosanitary restrictions by multiple countries to prevent their introduction, thereby markedly influencing both intra- and international trade of fruit and vegetable commodities [8].

Economic impacts lead to implementation of strict quarantine regulations and trade barriers by importing nations to prevent the entry and establishment of invasive pest species [9-10]. The increasing concern among the people and environmentalists for pesticide free food has compelled the scientists and researchers to search for alternative fruit fly management options [11]. In 2014, India's mango exports were prohibited by the European Union as a consequence of fruit fly infestation concerns.

Management of these pests is difficult because fully developed third-instar larvae of fruit flies leave infested, decaying fruits and fall into the soil to pupate. Thus, both larvae and pupae remain protected from insecticide applications targeted at the fruit surface [12]. Effective control of fruit flies requires a thorough understanding of their biology, enabling the targeting of vulnerable stages within the pest's life cycle [13]. However, the indiscriminate and excessive application of insecticides has been associated with significant ecological disturbances, posing serious risks to environmental integrity, human health, and non-target beneficial organisms [14]. Reliance on chemical insecticides presents gives rise to several limitations, like the development of insecticide resistance and pesticide residues issues hence there is the need for development of environmental friendly control measures [15].

Major fruit fly species in India

Common name	Scientific name
Mango fruit fly	*Bactrocera* (*Bactrocera*) *dorsalis* (Hendel)
Peach fruit fly	*Bactrocera* (*Bactrocera*) *zonata* (Saunders)
Guava fruit fly	*Bactrocera* (*Bactrocera*) *correcta* (Bezzi)
Caryea fruit fly	*Bactrocera* (*Bactrocera*) *caryeae* (Kapoor)
Carambola fly	*Bactrocera* (*Bactrocera*) *carambolae* Drew & Hancock
Malaysian fruit fly	*Bactrocera* (*Bactrocera*) *latifrons* (Hendel)
Invasive fruit fly	*Bactrocera* (*Bactrocera*) *invadens* Drew, Tsuruta & White
Melon fly	*Bactrocera* (*Zeugodacus*) *cucurbitae* (Coquillett)
Pumpkin fruit fly	*Bactrocera* (*Zeugodacus*) *tau* (Walker)
Cucurbit fruit fly	*Bactrocera* (*Zeugodacus*) *scutellaris* (Bezzi)
Three-striped fruit fly	*Bactrocera* (*Hemigymnodacus*) *diversa* (Coquillett)

Life cycle of fruit fly
Adult females oviposit on decomposing fruit and vegetable substrates. Individual fecundity may reach up to 500 eggs per female under optimal conditions. Eggs hatch leading to

the emergence of larvae, which undergo two successive moultings to attain the third (final) instar. These larvae after hatching start to tunnel inside the fruit and feed. Once these third instar maggots become fully feed they leave the rotting fruit and fall to the ground for pupation. The larval skin of the third instar becomes hard to form the puparium in which the maggots pupate. The adult flies emerge from the puparium by cutting a hole in it. Several generations are completed in a year depending on the host availability and favourable conditions [16-17]. Under favourable summer thermal conditions, the holometabolous development from oviposition to adult is typically completed within 8–10 days. Post-emergence, adults attain sexual maturity rapidly, with mating occurring within a few hours, and oviposition initiating approximately 24 hours thereafter.

Nature of damage

They inflict substantial damage to horticultural crops by ovipositional puncturing, wherein females insert eggs into host tissues, followed by larval development within the fruit. After hatching, the larvae feed within the decomposing fruit tissues, leading to rapid rotting; resulting in rapid fruit rot with no edible value and causing fruit drop. They directly damage the important export crops which may lead to losses of about 40% to 80% or even more, depending on the crop variety, growing region and growing season [18].

Management

In the current scenario, the growing requirement for pesticide-free fruits has brought focus on alternative pest management approaches, such as trapping systems, thereby promoting the adoption of eco-friendly strategies for insect pest management [19]. Fruit flies cannot be managed by a solo management tactic so more than one tactic is required for their effective management.

1. Cultural method

Cultural control measures are predominantly based on orchard sanitation and crop hygiene, targeting the disruption of life cycle progression of insect pests [16]. A study demonstrated that effective crop sanitation practices significantly suppress fruit fly emergence, with deep burial of infested fruits at 0.46 m completely preventing adult eclosion, while augmentoria and screening methods also provided substantial control [20]. Sanitation using augmentoria may serve as a key component of agroecological pest management by suppressing fruit fly populations, disrupting their life cycle, facilitating parasitoid release, and supporting compost production, thereby contributing to reduced dependence on chemical pesticides [21]. A 100% sequestration rate was observed in all treatments, demonstrating complete prevention of Adult fly escape irrespective of mesh type or species.

It has been observed that fallen fruits are major breeding sites for *Bactrocera invadens*, with significantly higher infestation levels than fruits on trees, indicating the critical importance of orchard sanitation in fruit fly management [22]. Collection of infested fruits in fastened black plastic bags followed by sun exposure leads to decomposition, causing effective mortality of fruit fly larvae [23-24]. According to a study fruit fly infestation in mango increases with fruit maturity, rising from <4% at immature stages to 14–16% at ripeness, indicating that early harvesting can effectively reduce damage [25]. Early harvesting of mature fruits, along with intensive and deep soil raking and tillage operations during peak summer and winter periods, facilitates the disruption of pupation sites by exposing concealed pupae to harsh environmental conditions and enhanced predation by natural enemies [26].

Host plant resistance is a key component of integrated pest management programs, as it provides an environmentally safe approach and does not impose additional costs on farmers [27-28]. There is significant potential to introgress resistance genes from wild cucurbit relatives into cultivated genotypes through wide hybridization, enabling the development of melon fruit fly–resistant varieties [29].

Crop	**Genotypes**	**Remarks**
Bitter gourd	IHR 89 and IHR 213	Resistant, thick and tough fruit rind
Pumpkin	IHR 35, IHR 40, IHR 79-2, IHR 83, and IHR 86	High resistance
Bottle gourd	NB 22, NB 25, NB 28, and Pusa Smooth Purple Long	Moderate resistance
Sponge gourd	NS 14	Moderate resistance
Ridge gourd	NR 2, NR 5, and NR 7	Moderate resistance
Round melon	Arka Tinda	Resistance
Wild melon	*Cucumis callosus*	High resistance

(**Source:** https://www.researchgate.net/publication/6677688)

2. Mechanical control

In recent years, fruit bagging has been increasingly recommended as a prophylactic intervention to mitigate infestation by fruit flies across diverse fruit crops [30]. In this technique, individual fruits, fruit clusters, or berries are enclosed within bags on the plant for a defined duration. It effectively suppresses fruit fly infestation, minimizes avian damage, and reduces the incidence of pathogenic infections. Additionally, it lowers pesticide residue levels and enhances the edible quality of the fruit [31]. Wrapping of fruits should be done before the attack of fruit fly like at least one month prior to harvesting. Though this is a laborious practice but is an effective method to prevent the attack of fruit flies on fruits [32]. A study concluded that on-tree bagging provides greatest barrier protection to the fruits in summers leading to good quality with highest cost- benefit ratio [33].

3. Behavioural control

In this technique, para-pheromonal lures are employed against fruit flies which mimic the natural pheromones produced by fruit flies. These pheromones are used to attract and trap male flies, allowing for population monitoring and infestation assessment [34]. E-coniferyl alcohol (E-CF) has also been found to be effective in attracting female *B. dorsalis*.

3.1 Male Annihilation Technique (MAT)

The primary objective of the Male Annihilation Technique (MAT) is to suppress the male population density to such an extent that successful breeding activity is either prohibited or reduced to negligible levels [23, 35]. Parapheromonal attractants are formulated as both liquid formulations and polymeric plugs developed for controlled release. The principal chemical lures used comprise of : Methyl eugenol (1,2-dimethoxy-4-(2-propenyl)benzene); Cuelure (4-(p-hydroxyphenyl)-2-butanone acetate); Trimedlure (tert-butyl-4,5-chloro-2-methylcyclohexane-1-carboxylate); Terpinyl acetate (α,α,4-trimethyl-3-cyclohexene-1-methanol acetate); and Vertlure (methyl-4-hydroxybenzoate) [32,36].Clear advantages for control and eradication programs can be realized through the reduction in application density of the Male Annihilation Technique (MAT) against *Bactrocera dorsalis*. Such as approximately a 50% decrease in material input, along with reduction in labour expenditures [37].

Species	Parapheromones Effective	References
B. nigrofemoralis	Cuelure , Baculure	[38, 39]
B. dorsalis	Methyl eugenol	
B. zonata	Methyl eugenol	
B. diversa	Methyl eugenol	
B. cucurbitae	Cuelure , Baculure	
B. scutellaris	Cuelure ,Baculure	
B. tau	Cuelure , Baculure	
Daucus longicornis	Cuelure	
D. shpaeroidalis	Cuelure	

Owing to the inherent instability of pheromones—manifested through processes such as photo-oxidation, auto-oxidation, isomerization, and high volatility–the development of formulations for field applications requires substantial refinement, particularly with respect to controlled or slow-release mechanisms [40]. The nanogel exhibited high chemical, thermal, and mechanical stability. The nanogel impregnated with methyl eugenol (ME) showed prolonged retention of the pheromone, enabling sustained release. Furthermore, it maintained significant attractant efficacy towards target pests because of the enhanced shelf life of ME within the nanogel matrix compared to pure ME, which exhibits rapid volatilization. The nanogel is inherently non-toxic and functions exclusively as an attractant source for fruit flies [41].

The management of fruit flies predominantly relies on the application of food-based attractants, such as hydrolyzed proteins or their ammonium analogues, combined with a toxicant. This approach is referred to as the Bait Application Technique (BAT). The principle underlying the Bait Application Technique (BAT) is based on the protein requirement of female fruit flies, which is essential for attaining reproductive maturity and enabling the deposition of viable eggs [42]. These bait formulations are designed to attract both male and female fruit flies, thereby enhancing control efficiency. The Bait Application Technique (BAT) exerts minimal impact on natural enemies and pollinators. Additionally, this approach is comparatively less time-intensive and requires reduced labour input.

3.2 Sterile Insect Technique (SIT)

The development and operational implementation of the Sterile Insect Technique (SIT) began in the 1950s in the United States under the leadership of Edward F. Knipling. The sterile insect technique (SIT) offers an eco-friendly, species-specific approach for controlling pest populations [43]. This effort led to one of the most successful area-wide integrated pest management (AW-IPM) programs, initiated in 1958 to eradicate the New World screwworm, a highly destructive parasite affecting livestock in the southeastern USA [44]. The Sterile Insect Technique (SIT) is an auto suppressive pest management strategy involving the mass rearing of target species, followed by radiation-induced sterilization and subsequent release of sterile individuals to suppress or eradicate field populations through breeding failure [45]. Reproductive coupling between radiation-sterilized males and fertile conspecific females leads to complete reproductive failure, yielding no viable offspring [46], while male offspring survive to continue spreading the gene [47]. In a study conducted demonstrated that the integration of the Sterile Insect Technique (SIT) with augmentative biological control significantly reduced *Anastrepha ludens* populations, achieving up to 98% suppression and highlighting its effectiveness in area-wide pest management [48]. Irradiation of pupae of *Bactrocera zonata* at 50–90 Gy significantly reduced female fecundity and egg hatchability when sterile males were released at a 1:1 ratio. However, maximum suppression was achieved when males irradiated at 90 Gy were released at four times the wild male population, reducing egg hatchability to ~5% and showing highest mating competitiveness, along with noticeable effects on wing morphometrics [49].

3.3 Use of foodbaits

Management of fruit flies mainly depends upon the use of food baits (hydrolyzed proteins or their ammonium mimics) mixed with an agent used for killing. This technique is known as the Bait Application Technique (BAT). These lures are used to attract both male and female fruit flies. Foodbaits are not specific to species and are less efficient in comparison to the male lures. In market foodbaits are procurable in both liquid and dry synthetic forms. Available liquid foodbaits include ammonium salts, protein hydrolysates, yeast products and the three component lure made up of ammonium acetate, putrescine and tri methylamine. GF-120 (Success® Apart), Sol Bait, Nulure and Buminal are some of the commercial baits which are presently available in the market. Bait Application Technique has minimum effect on natural enemies and pollinators. This method is less time consuming and less laborious.

Biological control

Nnatural enemies of fruit flies can also contribute in their management as they are relatively safer, sustainable and economic. Over the past decade, increasing restrictions on chemical control measures in fruit crops, coupled with heightened awareness of food security, have intensified. Consequently, phytosanitary and quality standards for export to developed countries have become more stringent, imposing greater restrictions on exporters and adversely impacting export quantities [50]. So biological control has to be promoted. This issue may be partially mitigated through the deployment of parasitoids, particularly those targeting late instar larvae or pupal stages, which exhibit extensive foraging behavior on fallen or damaged fruits and are capable of penetrating fruit fissures to navigate through the pulp. Parasitoids among the biological control strategy are mostly exploited for fruit fly management [51].

It constitutes an additional ecologically compatible intervention that facilitates the reduction of conventional insecticide inputs, thereby supporting the development of sustainable agricultural systems [52]. A study evaluating the biocontrol efficacy of five parasitoid species—three indigenous to Africa, namely *Tetrastichus giffardii*, *Psyttalia cosyrae*, and *Psyttalia concolor*, along with two exotic species, *Fopius arisanus* and *Diachasmimorpha longicaudata*—against *Ceratitis capitata* and other tephritid fruit flies demonstrated that the Mediterranean fruit fly was most effectively parasitized by *P. concolor*, as evidenced by higher rates of egg and larval parasitism, whereas the remaining four species exhibited moderate levels of parasitization [53]. *Opiinae* spp. represent the most predominant group of parasitoids employed in tephritid fruit fly management programs. These larval endoparasitoids preferentially oviposit in early instar hosts localized within sub-epidermal fruit tissues. Furthermore, larval–pupal parasitoids such as *Tetrastichus* spp. (Eulophidae) may be strategically integrated to augment and synergize the parasitism efficiency of *Opiinae* spp., thereby enhancing overall biocontrol efficacy.

The patogenic efficacy of different entomopathogenic nematode (EPN) strains was assessed against the Mediterranean fruit fly, *Ceratitis capitata*. *Steinernema riobrave* (Sr TX) demonstrated the greatest effectiveness (>80% mortality) against *C. capitata*, with its performance affected by larval stage, population density, and environmental factors, highlighting its promise as a biocontrol agent [54]. *Steinernema carpocapsae* Weiser (*Neoaplectana carpocapsae*) was observed to induce notable killing rate in melon fruit fly populations, achieving high lethality after 6 days of treatment duration across a range of 5,000–5,000,000 nematodes per cup, and recording an average field mortality of 87.1% when applied at a rate of 500 infective juveniles per cm^2 of soil. The entomopathogenic fungi have also been used for the management of fruit flies resulting in stimulating effects. *Beauveria bassiana*, *Metarhizium anisopliae* and *Isaria fumosorosea* resulted in 90-100 per cent motrtlaity of *Rhagoletis cerasi* [55]. A study conducted demonstrated that entomopathogenic fungi caused low mortality in pupae (18.7–23.9%) but significantly higher mortality in emerging adults (41.9–88.0%), with effectiveness influenced by fungal species, dose, and exposure method, highlighting their potential as biocontrol agents against *C. capitata*. [56]

Baculoviruses are insect-specific viruses that replicate within the insect host and cause death. Among the baculovirus isolates identified and characterized, the nuclear polyhedrosis virus (NPV) has been found to be highly virulent to several insect species NPV studies have demonstrated its ability to reduce the number of fruit fly individuals in laboratory and field settings, thereby decreasing the damage caused by this pest. Moreover, NPV is safe for the environment and non-target organisms, making it a promising option for fruit fly management [57]. However, it is important to note that using pathogenic microorganisms, including viruses, for insect pest management is still in its early stages, and more research is needed to fully understand their potential and limitations. Baculoviruses, particularly NPV, have shown potential for controlling *B. dorsalis*, and further research is needed to integrate them into pest management programs effectively.

4. Post-harvest management

Post-harvest treatments are essential for meeting quarantine requirements, as the absence of such measures restricts the export of fruits and vegetables to high-value markets. In the management of fruit flies, commonly employed quarantine techniques include:

1. Heat treatment, which raises the temperature of the produce beyond the insect's tolerance threshold.
2. Cold treatment, which lowers the temperature below the level required for insect survival.
3. Irradiation with gamma rays to eliminate or sterilize the pest.

These approaches could be implemented by plant quarantine units and other experts at ports and border posts to ensure that only pest-free products are allowed to move between regions or countries.

5. Quarantine management

Tephritid fruit flies are regarded as one of the most significant groups of quarantine pests affecting fresh fruits and vegetables [58]. Stringent quarantine measures, supported by appropriate tools and infrastructure—such as taxonomic expertise, diagnostic equipment, traps, and attractant lures—should be implemented, along with the dissemination of fruit fly distribution maps to facilitate accurate detection and identification of various species[45].The third instar of *Anastrepha grandis* was identified as the most cold-tolerant stage, with an estimated phytosanitary cold treatment requirement of ~23 days at 1.0°C in *Cucurbita pepo* [59].However, complete mortality was observed within 14 days in small-scale trials, indicating the need for large-scale validation and possible optimization of treatment duration.

Conclusion

Fruit flies (Diptera: Tephritidae) continue to pose a serious threat to global horticultural production due to their high adaptability, rapid multiplication, concealed feeding behaviour and insecticide resistance. The limitations and risks associated with chemical control have necessitated a paradigm shift toward sustainable pest management strategies. In this context, eco-friendly approaches such as biological control, behavioural techniques including the Sterile Insect Technique (SIT) and Male Annihilation Technique (MAT), along with strict quarantine measures, have emerged as effective alternatives. A holistic integration of these strategies within an IPM framework is essential for achieving long-term, environmentally sound, and economically sustainable management of fruit fly populations.

Author contributions

AS and SS conceptualized and developed the study framework. AS and SS prepared the preliminary draft of the manuscript and contributed to editing and refining different manuscript sections. Both authors reviewed and approved the submitted version.

Conflicts of Interest

The authors declare they have no conflicts of interest.

References

1. Ravichandra NG. Horticulture and its role in the national economies. In: Ravichandra C (Ed.), Horticultural Nematology. Springer, New Delhi, 2014, 1–3.
2. Dias NP, Zotti MJ, Montoya P, Carvalho IR, Nava DE. Fruit fly management research: A systematic review of monitoring and control tactics in the world. Crop Protection,2018:112:187-200.
3. Baral K, Roy BC, Rahim KMB, Chatterjee H, Mondal P, Mondal D, *et al*. Socio-economic parameters of pesticide use and assessment of impact of an IPM strategy for the control of eggplant fruit and shoot borer in West Bengal, India. Technical Bulletin No. 37, AVRDC publication number 06-673, AVRDC–The World Vegetable Center, Shanhua, Taiwan, 2006, 35pp.
4. Mumford JD. Integrated Management of Fruit Flies in India. Final Technical Report. RNRRS, Crop Protection Project R8089/8440 (ZA 0493/0664), 2006, 194.

5. Ndiaye M, Dieng EO, Delhove G. Population Dynamics and On-Farm Fruit Fly Integrated Pest Management in Mango Orchards in the Natural Area of Niayes in Senegal. Pest Management in Horticultural Ecosystems,2008:14:1-8.
6. Sultana S, Baumgartner JB, Dominiak BC, Royer JE, Beaumont LJ. Potential impacts of climate change on habitat suitability for the Queensland fruit fly. Scientific Reports,2017:7:13025.
7. Chauhan A, Daroch RK, Sharma R, Chandel VGS, Sharma S, Thakur KS, *et al*. Genetic diversity analysis of *Trialeurodes vaporariorum* (Hemiptera: Aleyrodidae) populations infesting vegetables in low and mid hills of Himachal Pradesh. Oriental Insects,2025:59:1–14. https://doi.org/10.1080/00305316.2025.2606306
8. Choudhary J, Naaz N, Prabhakar C, Das B, Maurya S, Kumar S. Field Guide for Identification of Fruit Fly Species of Genus *Bactrocera* Prevalent in and around Mango Orchards. Technical booklets No.: R-43/Ranchi-16. ICAR Research Complex for Eastern Region, Research Centre, Ranchi, 2014, 1-16.
9. Sharma S, Thakur M. Role of plant quarantine in the management of pest organisms- A Review. Agricultural Reviews,2007:28(4):235-244.
10. Sharma S, Bhardwaj SP, Bhardwaj S. Quarantine and locust control operations in India. Journal of Insect Science,2009:22(4):329-342.
11. Navarro-Llopis V, Vacas S, Sanchis J, Primo J, Alfaro C. Chemosterilant bait stations coupled with sterile insect technique: An integrated strategy to control the Mediterranean fruit fly (Diptera: Tephritidae). Journal of Economic Entomology,2011:104(5):1647–1655.
12. Heve WK, El-Borai FE, Carrillo D, Duncan LW. Biological control potential of entomopathogenic nematodes for management of Caribbean fruit fly, *Anastrepha suspensa* Loew (Tephritidae). Pest Management Science,2017:73:1220–1228.
13. Sharma I, Sharma S, Dubey VK. Management of fruit flies: An integrated approach, Chapter 5, pp. 57–67. In: Futuristic trends in agriculture engineering & food sciences, 2024, 3. IIP Publishers.
14. Mishra RR. Adoption of genetically modified crops can ensure food security in India. National Academy Science Letters,2020:43(2):213-217.
15. El-Gendy IR. Insecticide resistance of a field strain of Mediterranean fruit fly, *Ceratitis capitata* (Wiedemann). EgyptianJournalof Applied Sciences,2018:18(1):25–32. https://doi.org/10.3923/jas.2018.25.32
16. Singh H. Management strategies for fruit flies in fruit crops: A review. International Journal of Food and Nutritional Sciences, 2021, 10(2).
17. Sharma S, Nayak RK, Singh J. Insect-Pests and Diseases of Temperate Fruits and their Management. In: Wajid H, Verma B, Minnatullah Md (Eds.). Pests and Disease Management of Horticultural Crops. Biotech Books, New Delhi, 2023, 41-62. https://www.biotechbooks.in978-81-7622-543-4
18. Kibira M, Affognon H, Njehia B, Muriithi B, Mohamed S, Ekesi S. Economic evaluation of integrated management of fruit fly in mango production in Embu County, Kenya. African Journal of Agricultural and Resource Economics,2015:10:343-353.
19. Sharma RK, Khokhar Y, Singh S. Management of fruit flies (*Bactrocera* spp.) in guava (*Psidium guajava*) by pheromone traps. Indian Journal of Agricultural Sciences,2022:92:14-17.
20. Klungness LM, Jang EB, Mau RF, Vargas RI, Sugano JS, Fujitani E. New sanitation techniques for controlling tephritid fruit flies (Diptera: Tephritidae) in Hawaii. Journal of Applied Sciences and Environmental Management,2005:9(2):5-14. http://hdl.handle.net/1807/6447
21. Deguine JP, Atiama-Nurbel T, Quilici S. Net choice is key to the augmentorium technique of fruit fly sequestration and parasitoid release. Crop protection,2011:30(2):198-202.
22. Rwomushana I. Bioecology of the invasive fruit fly *Bactrocera invadens* (Diptera:Tephritidae) and its interaction with indigenous mango infesting fruit fly species. PhD thesis, Kenyatta University, Kenya, 2008, 220.
23. Reddy KV, Devi YK, Komala G. Management Strategies for Fruit Flies in Fruit crops–A Review. JETIR,2020:7(12):1472-1480.
24. Chauhan N, Chauhan A, Sharma S, Verma P. Organic Cultivation of Plum (*Prunus salicina* Lindl.). In: Ghosh SN, Krishna H, Rymbai H (Eds.). Organic culture of temperate fruit plants. Gyanavi Publishes & Distributors, New Delhi, 2024, 175-192.
25. Grechi I, Preterre AL, Caillat A, Chiroleu F, Ratnadass A. Linking mango infestation by fruit flies to fruit maturity and fly pressure: A prerequisite to improve fruit fly damage management via harvest timing optimization. Crop Protection,2021:146:105663.
26. Vadivelu K. Biology and Management of ber fruit fly, *Carpomyia vesuviana* Costa (Diptera: Tephritidae): A review. African Journal of Agricultural Research,2014:9(16):1310-1317.
27. Ganie SA, Rehman SA, Nisar T, Paray MA, Bano P, Khurshid R. Fruit Fly Management and Control Strategies: A Review. Biopesticides International,2022:18(2):89-100.
28. Sharma S, Chauhan S, Daroch RK, Verma JS. Plant defense mechanisms in insect and mite pest management: A review. International Journal of Agriculture and Plant Science,2026:8(1):8-14.
29. Dhillon MK, Singh R, Naresh JS, Sharma HC. The melon fruit fly, *Bactrocera cucurbitae*: A review of its biology and management. Journal of Insect Science,2005:5(1):40. https://doi.org/10.1093/jis/5.1.40
30. Navale SM, Walunj AR, Kadam UK, More PE. Management of fruit fly, *Bactrocera dorsalis* (Hendel) through fruit bagging in custard apple. Pest Management in Horticultural Ecosystems,2024:30(2):368-370.
31. Kumar M, Singh V, Jat R, Ahamad S, Kumar V. Pre-harvest fruit bagging for quality improvement in fruit crops: A review. The Pharma Innovation Journal,2021:10(7):530-541.
32. Badii KB, Billah MK, Afreh-Nuamah K, Obeng-Ofori D, Nyarko G. Review of the pest status, economic impact and management of fruit-infesting flies (Diptera: Tephritidae) in Africa. African Journal of Agricultural Research,2015:10:1488–1498.
33. Abbasi NA, Chaudhary MA, Ali MI, Hussain A, Ali I. On tree fruit bagging influences quality of guava harvested at different maturity stages during summer. International Journal of Agriculture and Biology,2014:16:543–549. http://www.fspublishers.org
34. Jaffar S, Rizvi SAH, Lu Y. Understanding the invasion, ecological adaptations, and management strategies of *Bactrocera dorsalis* in China: A review. Horticulturae,2023:9(9):1004.

35. Mariadoss A, Samson DG, Vinay T, Alice J, Sujeetha RP. Species diversity of fruit flies in different varieties of mango in Ranga Reddy District of Telangana State, India. Journal of Entomology and Zoology Studies,2020:8:184–189.
36. Istatu PS, Chauhan S, Rana A, Sharma S, Dhiman P. Integrated Pest Management (IPM) Approaches. In: Bhatia RK, Kumari N (Eds.). Advancements in Pest Management for Sustainable Agriculture. Academic Publication, Delhi, 2025, 25-42.
37. Manoukis NC, Vargas RI, Carvalho L, Fezza T, Wilson S, Collier T, *et al*. A field test on the effectiveness of male annihilation technique against *Bactrocera dorsalis* (Diptera: Tephritidae) at varying application densities. PLoS One,2019:14(3):e0213337.
38. Stanley J, Gupta JP, Rai D. Population dynamics of fruit flies, *Bactrocera* Spp. in northwestern Himalaya. Indian Journal of Entomology,2015:77(3):214-220.
39. Prabhakar CS, Sood P, Mehta PK. Fruit fly (Diptera: Tephritidae) diversity in cucurbit fields and surrounding forest areas of Himachal Pradesh, a North Western Himalayan state of India. Archives of Phytopathology and Plant Protection,2012:45(10):1210-1217.
40. Heuskin S, Verheggen FJ, Haubruge E, Wathelet JP, Lognay G. The use of semiochemical slow-release devices in integrated pest management strategies. Biotechnologie, Agronomie, Société et Environment,2011:15:459–470.
41. Bhagat D, Samanta S, Bhattacharya S. Efficient Management of Fruit Pests by Pheromone Nanogels. Scientific Reports,2013:3:1294. https://doi.org/10.1038/srep01294
42. Allwood AJ, Vueti ET, Leblanc L, Bull R. Eradication of introduced *Bactrocera* species (Diptera: Tephritidae) in Nauru using male annihilation and protein bait application techniques. Turning the tide: the eradication of invasive species. Proceedings of the international conference on eradication of island invasives (Occasional Paper of the IUCN Species Survival Commission No. 27), 2002, 19-25.
43. Ant T, Koukidou M, Rempoulakis P, Gong HF, Economopoulos A, Vontas J, *et al*. Control of the olive fruit fly using genetics-enhanced sterile insect technique. BMC biology,2012:10(1):51.
44. Dyck VA, Hendrichs J, Robinson AS. Sterile Insect Technique: Principles And Practice. In: Area-Wide Integrated Pest Management (2nd ed.). CRC Press, New York, 2021, 1216.
45. Plá I, García de Oteyza J, Tur C, Martínez MÁ, Laurín MC, Alonso E, *et al*. Sterile insect technique programme against Mediterranean fruit fly in the Valencian community (Spain). Insects,2021:12(5):415.
46. Abd-Elgawad MM. The Mediterranean fruit fly (Diptera: Tephritidae), a key pest of citrus in Egypt. Journal of Integrated Pest Management,2021:12(1):28.
47. Choudhury S, Logeswaran K, Keerthana A, Adhikari A, Ali H, Sharma S, *et al*. Insect Pests Control of Crops and Biotechniques: A Comprehensive Approach. In: Ali H, Xiao Y (Eds.). Genome Editing for Pest Management (1st Edition). CRC Press (Taylor & Francis Group), 2025, 72-81. https://doi.org/10.1201/9781003478706-6
48. Diouf EG, Brévault T, Ndiaye S, Faye E, Chailleux A, Diatta P, *et al*. An agent-based model to simulate the boosted Sterile Insect Technique for fruit fly management. Ecological Modelling,2022:468:109951.
49. Draz KA, Tabikha RM, El-Aw MA, Darwish HF. Impact of gamma radiation doses on sperm competitiveness, fecundity and morphometric characters of peach fruit fly *Bactrocera zonata* (Saunders)(Diptera: Tephiritidae). Journal of Radiation Research and Applied Sciences,2016:9(3):352-362.
50. Melo O, Engler A, Nahuelhual L, Cofré G, Barrena J. Does Sanitary and Phytosanitary regulation stringency affect developing countries exports? Evidence from Chilean fruit exports. World Development,2014:54:350-359.
51. Vargas RI, Leblanc L, Harris EJ, Manoukis NC. Regional suppression of *Bactrocera* fruit flies (Diptera: Tephritidae) in the Pacific through biological control and prospects for future introductions into other areas of the world. Insects,2012:3(3):727-742.
52. Paranhos BJ, Nava DE, Malavasi A. Biological control of fruit flies in Brazil. Pesquisa Agropecuária Brasileira, 2019, 54.
53. Mohamed SA, Ekesi S, Wharton R, Lux SA, Overholt WA. Old and new host-parasitoid associations: parasitism of the native African and invasive fruit flies species. Proceedings of the 5th International Symposium on Biological Control of Arthropods, Langkawi, Malaysia, 2017, 224–227. https://doi.org/10.1079/9781786394118.0224
54. Gazit Y, Rossler Y, Glazer I. Evaluation of entomopathogenic nematodes for the control of Mediterranean fruit fly (Diptera: Tephritidae). Biocontrol Science and Technology,2010:10:157–164.
55. Daniel C, Wyss E. Migration and spread of cherry fruit flies within orchards-the possibility of biological soil treatment. Mitteilungen der Deutschen Gesellschaft für allgemeine und angewandte Entomologie,2009:17:247-248.
56. Beris EI, Papachristos DP, Fytrou A, Antonatos SA, Kontodimas DC. Pathogenicity of three entomopathogenic fungi on pupae and adults of the Mediterranean fruit fly, *Ceratitis capitata* (Diptera: Tephritidae). Journal of Pest Science,2013:86(2):275-284.
57. Zhang W, Gu Q, Niu J, Wang JJ. The RNA Virome and Its Dynamics in an Invasive Fruit Fly, *Bactrocera dorsalis*, Imply Interactions Between Host and Viruses. Microbial Ecology,2020:80:423–434.
58. Hallman GJ, Loaharanu P. Generic ionizing radiation quarantine treatments against fruit flies (Diptera: Tephritidae) proposed. Journal of Economic Entomology,2002:95(5):893-901.
59. Hallman GJ, Maset BA, Martínez EIC, Barrios CEC, Vreysen MJ, Myers SW, *et al*. Phytosanitary cold treatment against *Anastrepha grandis* (Diptera: Tephritidae). Florida Entomologist,2017:100(1):29-31.