Menace of Fruit Flies and its Eco-friendly Management Practices Using Several Modern Techniques

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Abstract

Fruit flies are a significant agricultural pest that feeds on fruit and vegetable harvests. Because of the destruction these insects cause, they are regarded as essential pests. Managing fruit flies is challenging because they lay their eggs within the fruit. Their enormous capacity for reproduction, flexibility in a variety of settings and polyphagous lifestyle provide serious challenges to control. A solitary strategy is inadequate to address this pest; rather, a comprehensive approach that combines multiple methods, including non-chemical methods like, mechanical, cultural, behavioral and biological controls, along with plant resistance mechanisms, is necessary. Some environmentally friendly sustainable management techniques, such as pheromone traps, poison baiting, soil solarization, bio-control agents, biopesticides, etc. for fruit-fly control, alternative techniques have frequently been used in various horticultural crops because chemical methods are harmful to the environment and leave residues on crops, soil and air.

Introduction

According to Bebber et al. (2014), pests and crop diseases are becoming a more serious hazard to food security. Fruit flies are one of the major pests among other issues. Fruit flies, which comprise approximately 4000 species over 481 genera, are economically significant pests that fall under the Tephritidae family and order Diptera (Reddy et al., 2020). Roughly 5 percent of these species are discovered to be found in India (Mariadoss et al., 2020). Fruit flies have spread throughout the world as invasive pests of numerous horticulture crops because of their ability to adapt to different climates, extremely polyphagous behavior and the ability of some species to reproduce quickly (Mumford, 2006; Ndiaye et al., 2008).

Nature of Damage by fruit flies

Female fruit flies damage nearly 400 different horticultural crops by ovi-positioning inside the fruit. Controlling fully matured third-instar fruit

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fly larvae is extremely challenging because they choose to pupate in the soil by dropping on them after fruit decays. Thus, in this manner, both larvae and pupae can evade the pesticides that are applied to the fruit's surface stated by Heve et al. (2017).

The exit holes created for pupation by fully grown maggots on damaged fruit were extremely evident In the case of the mango; this was not the case with the sapota, guava, or banana. The mature maggot left the fruit and meandered aimlessly around the earth, looking for a good place to pupate (Kibira et al., 2015). The nature of damage and crop loss in some economically important fruit crops have been discussed below.

Cucurbits

About sixteen cucurbit crops are susceptible to assault by *Zeugodacus cucurbitae*, the cucurbit fruit fly, and *Zeugodacus tau*. The quality and yield of cucurbit fruits were both decreased by infection, even if the rate of attack differs among the crops (Nair and Pal, 2020). Through the ovipositional puncture, a watery fluid emerges which turns the fruit's skin into a brownish color deposit (Dhillon et al., 2005). The larvae entered into the fruit pulp, while consuming it. The fruits that are infected get malformed. Fruit tissues decompose as a result of saprophytic microorganisms entering through ovipositional punctures (Nair et al., 2017).

Guava

Bactrocera spp., fruit flies that create infestations in guavas, yield creamy white, yellow, or pink flesh and an aromatic edible rind. According to Patel et al. (2007), the fruit releases a strong, musky smell as it ripens, which attracts fruit flies. The oviposition marks are hard to see at first. Still, after the eggs hatch, after an incubation period, maggots that consume the tissue become apparent, manifesting as a discernible area encircled by a brownish mark around the puncture site within one to two days which has been proved by Sarwar (2006), and Riaz and Sarwar (2013). After this phase, the flesh starts to decay due to microbial breakdown, prompted by the damage inflicted by the maggots.

Mango

According to Ratna et al. (2016), the ripening stage of the mango fruit gives female fruit flies (*Bactocera dorsalis*) the necessary choice to locate the spot when it comes time for oviposition. Mohd Noor et al. (2011) illustrated that matured fruit is preferable for the growth of B. dorsalis larvae, facilitating smoother ovipositor penetration (Yashoda et al., 2007), while Messina and Jones (1990) viewed fruit firmness and ripeness level as probable determinants of host suitability for female flies. Bansode (2009) noted that tainted fruits pose a hazard to consumption.

Crop Loss and economic consequences incurred

Fruit flies puncture vegetables to deposit eggs and develop larvae within the fruit, causing severe harm simultaneously (Aluja, 1994). Important export crops are directly harmed, potentially resulting in 40% to 80% or more crop losses, depending on the crop type, variety, cultivation conditions and seasonal factors. Depending on their range, habitat, and time of year, these pests directly damage a variety of plants, causing losses of 40–80% (Kibira et al., 2015).

Contingent upon the sensitivity of the crop species and the surrounding ecological conditions, according to Dhillon et al. (2005) and Shooker et al. (2006), the damages vary from 30 - 100%. Among the 400 fruit fly species globally, *Bactrocera dorsalis* (Hendel) emerges as the most harmful pest (Verghese et al., 2008), causing a depletion in mango yields by 25–50% when harvested at full ripeness. Under epidemic pest outbreaks, the damage level could increase by up to 80% stated by Abdullah et al. (2002) and Latif (2004). This species also adversely affects papaya, guava, and sapota besides mango (Jiji et al., 2009).

Fruit flies are perceived as highly detrimental to guava fruit production, leading to declines in productivity and quality deterioration (Vargas et al., 2008). Based on the crop type, location and season, 20 to 80 percent of losses in crops due to fruit flies occur, according to data (Arora et al., 1998; Haseeb, 2007). Mishra et al. (2012) report annual agricultural losses in citrus, mango, guava, and sapota in India, amounting to Rs. 2945 crores. The degree of damage in cucurbits varies with the season and variety. *Z. cucurbitae* causes 41 - 89% of bitter gourd damage by numerous researchers (Kushwaha et al., 1973; Nair et al., 2021). An annual *Z. tau* infection accounts for between 30 and 40 percent of agricultural product losses in Asia by Li et al. (2020).

It has been estimated that fruit flies have the potential to inflict up to 100% of the harm on various fruit and vegetable crops (Kumar et al., 2011).

Management strategies for fruit flies

To control these pests, a variety of management techniques have been used. Of these, biological control has received the greatest research attention (29%), lagging behind chemical management (20%), behavioral management including SIT (18%), and isolation measures (17%) (Dias et al., 2018).

The pest deposits their eggs within maturing fruit, larvae mature within the fruit, and final-stage larvae migrate to undergo pupation in the ground, rendering them impervious to insecticides and difficult to regulate (Heve et al., 2017). Diverse tactics are essential for fruit fly management, as it is not feasible to control them solely through one method (Heve et al., 2017). Thus, safeguarding our crops from this menace demands the implementation of a range of integrated control measures.

Mechanical Control

Fly swatters, screens and nets, and environment management plans are examples of protective coverings. Since UV light attracts fruit flies more than other light, insect light traps have been the most used method (Badii et al., 2015). According to Dias et al. (2018), fruit wrapping, mass-trapping, and the removal of broken parts are also included in the mechanical management research. Mass trapping uses baits and traps releasing certain chemical compounds to draw insects inside traps by killing them (El-Sayed et al., 2009). The availability of strong and reasonably priced attractants is a prerequisite for mass trapping's efficacy as a manipulative tool (Villalobos et al., 2017).

Cultural Control

To manage the insect population and maintain hygiene, the fallen or overripened fruits should be carefully buried up to 50 cm deep in the ground (Reddy et al., 2020). About 80 percent of the infestation was reduced by raking or ploughing the soil twice: following the color change, apply once every two weeks, and then repeat the process three weeks later, reaching a depth of 6 cm around and beneath the canopy (Patel et al., 2005; Stonehouse et al., 2005).

Singh (2008) noted that the pear-shaped resistant type of guava, which has rough skin, is least vulnerable to *B. dorsalis* damage, while smooth-skinned guava cultivars including Red Flash, Allahabad Safeda, and Local are very sensitive. Because fruit flies favor depositing their eggs on fully matured fruits, harvesting the fruits early can aid in averting fruit fly infestations (Badii et al., 2015; Sidique et al., 2017). Another important tool for managing fruit flies is time-bound pruning (Choudhary et al., 2022).

Physical Control

A fruit fly-free zone may be established by removing abscised fruit from backyard trees' shade and using other techniques (Jenkins et al., 2008). The following post-harvest quarantine procedures are available and are being utilized in place of fumigation with hazardous pesticides (Robinson, 2005):

I) Heat treatment to raise the fruit's temperature beyond the pest's thermal limits.

II) Chilling technique for limiting the fruit's temperature below the fruit fly's thermal thresholds, and

III) Gamma radiation exposure from a Cobalt-60 or Caesium-137 source to eliminate the emerging pests.

According to Bansode (2009), the best outcome for controlling fruit flies in mango after harvest was achieved using a hot water treatment at 52^{0}C for 60 minutes. According to Singh (2008), eliminating the fruit makes sure that maggots don't make it to the pupae stage in the ground where they would eventually become adult flies. While the percentage of ruined fruits steadily dropped to roughly 20% when hygienic procedures were implemented, small portions of diseased fruit can be microwaved to destroy the maggots (Hasyim et al., 2008).

Behavioural Control

To achieve adequate management, Verghese et al. (2014) argued that integrated approaches involving IPM strategies such as field cleaning, tillage, pest control methods such as the Bait Annihilation Technique (BAT), and Male Annihilation Technique (MAT) are essential. Fruit flies have been noted to exhibit attraction towards the male attractant methyl eugenol (ME) at distances of up to 800 meters, as observed by Roomi et al. (1993). According to reports from many areas in India and beyond, MAT utilizing traps with methyl eugenol as an attractant is quite efficient against *Bactocera dorsalis* (Singh and Sharma, 2013).

Since they are the main factor in inhibiting fruit fly multiplication, the bait annihilation technique (BAT), combined with another element of management strategies, is one of the effective methods for suppressing female fruit flies (Ekesi, 2016). Various synthetic food baits, including compounds like ammonium salts, protein hydrolysates, yeast derivatives, and a three-component lure made up of ammonium acetate, putrescine, and trimethylamine, are accessible in both liquid and dry forms in the market (Ekesi and Billah, 2006). Examples of these commercial baits include GF-120 (marketed as Success® Apart), SolBait, Nulure, and Buminal (Ekesi et al., 2009; Vayssières et al., 2009).

Environmentally friendly and effective in open orchards even in unfavorable seasons. Pheromone nanogels have been effectively utilized to control *B. dorsalis* and fruit flies, and it is anticipated that they will be able to control additional insects in the future (Bhagat et al., 2013). Recently, artificial intelligence has been utilized to determine when to expose flies to radiation. The hue of the eyes, which changes depending on the physiological stage of the pupae, has been utilized for determining the emergence timing of adult flies (González-López et al., 2022).

According to Van der Vloedt and Klassen (2006), the natural reproductive cycle of insects is disrupted by the Sterile Insect Technique (SIT) deliberately by using sterilized populations of fruit fly males to mate with viable females in the wild population. Due to its species-specificity and relative environmental safety, SIT is highly favorable (Hendrich et al., 2002; IAEA, 2003). Two notable instances of Sterile Insect Technique (SIT) in the Neotropics include successful initiatives targeting *Anastrepha ludens* (Mexican fruit fly), and recent triumphs in eradicating *Ceratitis capitata* (Mediterranean fruit fly), as highlighted by Perez-Staples et al. (2021).

Host Plant Resistance and Genetic Control

These don't harm the environment and don't require the farmers to incur more expenses. Resistance genes from the wild family of cucurbits have been found to have been transferred into cultivated genotypes through extensive hybridization, allowing for the growth of fly-resistant melon varieties (Dhillon et al., 2005).

RNA interference (RNAi), a technique of gene regulation and an antiviral defense system in cells has been used to affect genetic control in fruit flies. This has led to the sequence-specific destruction of mRNAs (Huvenne and

Smagghe, 2010; Palli, 2012). The evaluation of gene silencing and RNAi expression has been extensively recorded in research using *B. dorsalis* (Chen et al., 2008), *Bactrocera minax* (Xiong et al., 2016), *Anastrepha suspensa* (Schetelig et al., 2012), and *C. capitata* (Gabrieli et al., 2016). CRISPR-Cas9 is utilized to achieve genetic biocontrol for several pests, including *Bactrocera tryoni* (Choo *et al.*, 2018), *B. dorsalis* (Zhao et al., 2019), *Ceratitis capitata* (Meccariello et al., 2017), *Zeugodacus cucurbitae* (Paulo et al., 2022), and *B. oleae* (Koidou et al., 2020).

Biological Control

Biological control has been extensively studied (Garcia et al., 2020), among the pest control programs According to Srinivasan (1994), *Opius fletcheri* is the most important parasitoid of *B. cucurbitae*. To manage *C. capitata* populations in olive orchards, *Diachasmimorpha longicaudata* was employed in Peru in the 1990s (Garcia et al., 2020). The most prevalent class of parasitoids commonly employed for controlling the pest is *Opines* spp. The juvenile fruit fly larvae that are eating beneath the fruit's epidermis are parasitized by these larval parasitoids. The activity of *Opines* spp. can also be supplemented by larval-pupal parasitoids such as *Terastichus* spp. (Eulophids) (Stibick, 2004).

Apart from parasitoids, entomopathogenic fungi and nematodes have also demonstrated stimulating effects when used to control fruit flies. For example, *Beauveria bassiana* (Balsamo), *Metarhizium anisopliae*, and *Isaria fumosorosea* (Wize) caused 91% mortality of *Rhagoletis cerasi* (L.) (Daniel and Wyss, 2009). The effectiveness of various biopesticides, including several entomopathogens, against fruit fly infestation on bottle gourds was assessed by Alam and Khan (2021).

Biorational method

It was observed that NSKE 5 percent worked well against *B. cucurbitae* (Tomar and Singh, 2001). Neemazal (@ 3 and 5 ml/l) showed a reduction of 70.5 percent damage and offered significant control against *B. cucurbitae* (Babu et al., 2002). Khattak et al. (2009) observed reduced fruit fly infestation when neem oil at 1, 1.5, and 2 percent and neem seed water extract at 1, 2, and 3 percent concentrations.

Under field conditions, Sharma et al. (2011) found that a drek seed kernel extract (1.0%) + diet was efficient in controlling *Bactocera tau* and fruit flies on tomatoes. When Dharek (*Melia azedarach*) extract was utilized, Kumar (2005) and Sharma (2008) found that it significantly inhibited *B. tau* oviposition and decreased egg laying and hatchability. Azadirachtin from neem, *Azadirachta indica* dramatically reduced the number of fruit flies by about 12 (Singh, 2003; Silva et al., 2013).

Conclusions

Due to the ambiguous habitat and damaging potential, the fruit fly is considered one of the dreaded pests in the horticultural ecosystem.

Several chemical pesticides are available for pest control but those become sometimes ineffective due to the hiding behavior of this pest inside the fruits or in the soil during the pupa stage. So, instead of going for chemical applications, the farmers should be encouraged for sustainable management of fruit flies to safeguard the natural ecosystem. Nowadays several molecular technologies have been found and several studies are going on to alter the genetic mechanism of fruit flies so that the damaging potential of the pest can be controlled intrinsically.

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