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Biological Control Program to Manage Fruit Fly Pests and Related Tephritids (Diptera: Tephritidae) in Backyard, Landscape and Garden

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Abstract

This prime fact discusses fruit fly's control strategy and gives the information needed to make decisions about controlling these pests from an area. Incredibly, fruit flies are annoying pests as they can destroy a range of fruits and vegetables in a very short space of time. Usually, fruit flies eat ripened fruit and vegetable and fermenting products, and typically remain in areas with suitable food sources. There are several pests described as fruit fly, but the main ones include *Bactrocera zonata* (Saunders), *Bactrocera cucurbitae* (Coquillett) and *Bactrocera dorsalis* (Hendel) that are problems for growers. The larvae (maggots) of the fruit fly feed inside the fruit, destroying the pulp and allowing the entry of secondary bacteria and fungi that rot the fruit and degrade the quality of the host. New research into the fruit fly control is geared to reduce the use of chemical insecticides and allow for agriculture that is more environmentally responsible. A range of fruit fly control and prevention methods can be used including by taking effective biological control action to minimize damage to the fresh fruits and vegetables for contributing on regional management strategies. In this regard, a range of natural enemies, both vertebrate and non-vertebrate, are known to reduce fruit fly populations in fruits and vegetables. Biological control of fruit fly might be accomplished through release and establishment of the predator, parasitoid, and pathogen. Fruit fly predators may include spiders, ants, carabid beetles, assassin bugs, staphylinid beetles and probably others that consume a number of pests such as birds and poultry. Most common parasitoids of fruit flies belong to the families Braconidae, Chalcididae and Eulophidae, and some examples are *Psyttalia fletcheri* Silvestri, *Diachasmimorpha kraussi*, and *Diachasmimorpha longicaudata*. These insects, mostly wasps and flies lay eggs on or near fruit flies pest of fruits and vegetables, and upon hatching, parasitoid's larvae feed on hosts, either internally or externally and kill hosts during their development. Bacteria pathogens infect their host when eaten, for instance endo-symbiotic bacteria of the genus Wolbachia are known to induce cytoplasmic incompatibility, thelytokous parthenogenesis and male-killing or feminization. Fungal pathogens for example green (*Metarhizium anisopliae*) and white (*Beauveria bassiana*) muscardine fungi can infect their hosts by penetrating directly through surface of host's body. As with the control of many other pest species, a single control method by itself is often not sufficient to provide high degree of control or even effectively eradicate the fruit flies on sustainable basis.

Keywords

Fruit Files, Fruit, Vegetable, Predator, Parasitoid, Pathogens, Biological Control

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1. Introduction

The fruit flies are terrible pests of horticulture and significantly infesting almost every commercial fruit orchards and vegetable farms. The fruit flies pests can be found throughout the world, and as their name suggests, these are commonly found infesting fruits. However, fruit flies are also capable of breeding in vegetables. While considered a general annoyance, fruit flies can be significant pests in food processing and handling structures. These comprise several different species mainly belonging to the genus Bactrocera of family Tephritidae, subfamily Tephritinae within order Diptera of class Insecta. The most common species encountered in horticulture and other structures are *Bactrocera zonata* (Saunders), *Bactrocera cucurbitae* (Coquillett) and *Bactrocera dorsalis* (Hendel) that severe as severe economic threat for the state's commercial growers. Like many other home or farm gardeners, when anyone wants to grow and eat his own fresh fruits and vegetables, perhaps fruit flies are already wreaking havoc in the gardens and destroying the produces in backyard (Sarwar, 2006 a; 2006 b; 2014 a; 2014 b).

Fruit flies are known for their rapid reproduction and relatively short lifespan. All fruit flies develop by complete metamorphosis and their life cycle is made up of four stages, egg, larva, pupa and adult. Most of the fly's life is spent as an adult, with development usually taking less than two weeks. The developmental time and overall lifespan is largely influenced by environmental conditions such as temperature and humidity. High temperature quickens the development and may extend lifespan, whereas cooler temperature may prolong larval and pupal developments and kill off adults. Adults can live for many weeks and flies commonly over-winter as adults, becoming active when the weather warms up around July and August and gradually the population builds up (Ovruski, 2002; Sarwar et al., 2014 a; 2014 b).

2. Damage by Fruit Flies

Fruit fly is responsible to be known as the worse insect by gardeners than any other pest. Outdoors, fruit flies are frequently active at all the times of the year, but their populations tend to build during the summer and becoming very abundant at harvest time of produce. Fruit flies often pose massive problems in orchards and farms, as the pests have the potential to ruin large amounts of fruit in a short time due to their quick development and ability to reproduce rapidly. The maggots hatch and by their feeding as well as bacteria they carry, cause the fruit to rot and fall. Feeding damage can cause premature fruit drop and reduces both the quality and quantity of fruit production. Large numbers of rotting fruits on the ground can create an undesirable mess, especially in landscaped situations (Kuzina, 2001; Sarwar et al., 2013).

3. Contamination Problems by Fruit Flies

Fruit flies are among insects causing a high percentage of contamination of fruits, vegetables and their products by depositing bacteria and other disease causing organisms. Because of their habits of visiting unsanitary sites, these have the potential to carry disease causing germs. Fruit flies have a lack of the piercing and sucking month parts like that of typical blood feeding flies, but possess sponging mouthparts similar to houseflies. It means in order to take a food; the fruit fly must deposit its saliva onto foodstuff and then suck up the solution. This process inevitably leaves behind bacteria on food that once remained inside the body of fly as well as on its legs and body. When fruits infested with fruit fly larvae are ingested accidentally, these may cause gastrointestinal discomfort and diarrhea (Sarwar et al., 2014 c).

4. Reproduction and Lifecycle

Fruit flies have rapid reproduction and short life span, and are largely influenced by environmental conditions such as temperature and humidity. Females can be distinguished from males by the presence of an ovipositor that is a dark-colored pointed structure at the end of the abdomen, which is used to pierce the fruit and lay eggs. The life cycle of fruit fly begins when a female fruit fly lays a small batch of eggs just beneath the skin of fruit. The larvae are referred to as maggots and are creamy white, tapering towards the head and between 7-9 mm long when fully grown. A typical fruit fly's larva is worm-like with no legs or eyes except for hook-like mouthpiece for feeding in the food medium. The newly hatched larvae then develop through three instars, with the entire process lasting about five days. After the eggs hatch, fruit fly larvae spend the first two larval instars by eating and burrowing throughout the fruit. The first instar typically includes for 24 to 25 hours of constant feeding and maturation. The maggot then sheds its outer skin (cuticle) and enters the second instar as a bigger and more defined larva. Larvae in the second instar continue tunnelling through fruit or other food sources for another 24 hours before molting again. During the third and final instar, larvae are fully grown and these crawl away from the food in search of safe and dry place to pupate and the maggot may darken in color during this period. Under optimal environmental conditions, the larval stage lasts for 5-6 days. When the

maggots leave the fruit and burrow into the soil to begin pupal stage, then larva encloses itself in a hard case for the pupal development which typically takes some days. Fruit flies emerge from the pupal case in approximately 10 days and live for several more weeks. After emerging from the pupa stage, the fruit fly reaches adulthood and female may begin procreating within two days.

5. Signs of a Fruit Fly's Infestation

Normally farmers encounter the damage symptom of fruit flies that causes direct damage by egg laying and in some cases indirect damage by germs transmission, to help in designing the most appropriate management strategies in their farming communities. The two most visible signs of fruit fly's activity would be the adult flies and the pupae. Adult flies often are seen flying around the gardens or farms and near the decaying fruits or vegetables. The mature larvae of fruit flies crawl out of the breeding material to pupate in a dry nearby spot. These sometimes are mistaken for cockroach or rodent droppings but can easily be differentiated by darken in color and hard case of the pupae. Some of damage symptoms of fruit flies are noting changes in size, color, feeding activity, areas showing fruit fly oviposition marks or fractures on fruits or vegetables, also infested fruits start to rot, watch larva emerging hole, confirm fruit fly infested fruits with the presence of eggs or larvae inside, and other relevant information on the damage.

6. Detection and Monitoring

The most efficient trap for monitoring the fruit flies is the glass or plastic McPhail-type trap baited with torula yeast lures. Yellow sticky traps baited with sex-pheromone lures (Cue lure, attract males of many *Bactrocera* and *Dacus* species, Methyl eugenol is attractive to male flies of many *Bactrocera* species) and ammonium carbonate, ammonium bicarbonate, or diammonium phosphate food bait (attractive to both sexes) also are commonly used to monitor fruit fly populations, but these generally are less efficient than McPhail traps.

7. Biological Controls

Working out the best ways to deal with fruit flies can be difficult, and using ineffective strategies can waste time, energy and money. Unfortunately, fruit flies are very difficult to control using purely organic methods; however, biological control can help to keep their numbers down (Yoder and Wharton, 2002; Sarwar, 2013 a; 2013 b; 2013 c; 2014 c; 2015; Sarwar et al., 2011 a; 2011 b). Following are few ideas and efforts which can help to have the benefit of the fruits and vegetables of our endeavors.

The fruit flies are attacked by a number of parasitic wasps, however, the common natural enemies may or do not provide acceptable control in commercial situations in an area. Some naturally occurring parasites are known to attack fruit flies, but these can or do not appear to provide adequate control. The best method for controlling the fruit fly depends on use of biological control agents (predators and parasitoids) and there can be relatively few instances that may be regarded as sustainable successes in an orchard or vegetable production situation. Fruit fly has no specific predator; invertebrate predators may include spiders, ants, carabid beetles, assassin bugs, staphylinid beetles and probably others. Generalist predators include ants and ground beetles that feed on maggots, spiders catch adults in webs, and predatory flying insects such as dragon flies and robber flies feed while flying (Hoelmer and Kirk, 2005; Mills and Daane, 2005) as well as other natural enemies (Riegler, 2002).

Ants Formica species are the most abundant predators on the ground and have been observed carrying and killing fruit fly pupae. Predation rates vary among orchards, depending on factors such as the species and densities of predators present and the soil depth at which fly pupae are located. Studies similarly indicate that arthropods can inflict substantial mortality on fruit fly pupae (Daane and Johnson, 2010; Tzanakakis, 2006). Insect predators such as lady beetles and lacewings are found in orchards, but because the fly's eggs are embedded underneath the fruit's epidermis and the larvae feed deep inside the fruit, the immature stages are protected from most generalist predators. Before the larva pupates, it creates a thin window on the fruit's surface through which it may be exposed to predators. If the fruit is still firm, the larva will often pupate inside. However, upon fruit maturation most fly larvae leave the older fruit, especially in the late summer and fall, and drop to the ground to pupate in the soil beneath the tree (Tzanakakis, 2006). For this reason, pupae while drop to the ground and walk to reach pupating site are exposed to and accessed by both flying and walking natural enemies to be predated or parasitized.

Flies are reduced by birds such as Swallows, Restless Flycatchers and Willy Wagtails that eat 81% of infested fruits. In consuming the fruits, these predators, unfortunately also consume parasitoids so there is an indirect adverse effect. In the endemic forest habitat, however, predation by fruit-eating vertebrates, such as birds and primates, results in marked reductions in fruit fly numbers. Generally, predators have little effect on fruit fly populations; however, increasing the range of habitats available will not give full control but will inevitably give a wide range of benefits (Bokonon-Ganta et al., 2007).

Poultry are an enormous help in fruit fly's control, so, orchard can be used as a poultry forage area. If it is designed in orchards to incorporate chooks these can reward by turning rotten fruits into eggs and happily spend hours in scratching beneath trees looking for fruit fly pupae. Adult fruit flies are trapped on the ground for up to 24 hours after emerging from the pupae as it takes a long time for their wings to harden. During this time the adult flies are also vulnerable to a roving chook. Where it is not possible to allow chooks free range, small demountable fences can be used under trees that are vulnerable to attack by fruit fly.

The use of parasitoids to control fruit flies biologically has always been a wide appeal, and tropical fruit flies in general, have proved to be good targets for biological control. The most documented research on using parasitoids to reduce fruit fly populations has been in Hawaii, where a large number of species have been introduced and released to control oriental fruit fly (*Bactrocera dorsalis*), Mediterranean fruit fly (*Ceratitis capitata*), and melon fly (*Bactrocera cucurbitae*). The parasitoids belong to the families Braconidae, Chalcididae and Eulophidae. Releases of a range of parasitoids resulted in up to 95% reductions in populations of Mediterranean and oriental fruit flies. Also, in normally heavily infested commercial fruits, levels of damage caused by fruit flies have been reduced to a point where fruits are virtually free from infestation. These results are mainly due to the establishment of the wasp *Fopius arisanus* and to a lesser extent, the establishment of *Fopius vandenboschii* and *Diachasmimorpha longicaudata*. Inundative releases of laboratory-reared parasitoids may be an appropriate option and is being researched (Duan and Messing, 2000; Wharton et al., 2000; Sime et al., 2006).

Two of the most common and widespread parasitoid wasps are *Fopius arisanus* and *Diachasmimorpha longicaudata*. The wasp *F. arisanus* is native to Asia; adult inserts its ovipositor into the fruit through the fruit fly's egg-laying puncture and lays a tiny egg inside the fruit fly's egg. The parasitoid larva lives inside the host (fruit fly larva) until the host has pupated in the ground. At that point, the parasitoid larva kills its host and completes its development, feeding on the host flesh. Consequently, a parasitoid emerges from the pupa instead of an adult fly. Females *F. arisanus* search for their hosts mostly on fruits in trees, and rarely forage on the ground. Because it attacks at the early stages of host's maturity, this species generally out competes to other parasitoid species. The wasp *D. longicaudata*, is native to the Indo-Pacific region, parasitoid infests third instar larvae of fruit flies, puncturing through the fruit's skin with its very long ovipositor. By preference, it attacks ripe and fallen fruits and spends lots of time foraging on the ground. There are occasions when levels of parasitism exceed 60%, but this is usually towards the end of a major fruiting season, e.g., guava. However, field control systems based on protein bait sprays take recognizance of the need to conserve parasitism levels that now occur naturally (Wang and Messing, 2003; Kent et al., 2011). The larval parasitoid, *Trybliographa daci* (Weld) (Hymenoptera: Eucoilidae) and pupal parasitoid, *Dirhinus giffardii* (Silvestri) (Hymenoptera: Chalcididae) released at a density of 3000 individuals per acre (7500 per hectares) proved the best for the management of fruit-flies in mango orchards (Kimani-Njogu and Wharton, 2002; Shah et al., 2014; Sarwar et al., 2015).

8. Host Specificity Trial by Imported Parasitoids of Fruit Fly

There are some variations in the materials and methods used to test the different species, but procedures are generally as described by Sime et al., (2007). Briefly, researchers use small cages (about 1 square foot) to isolate female parasitoids with either target (fruit fly) or nontarget hosts for 48 hours in a no-choice test. Target individuals and nontarget species are then placed together for a choice test for the next 48 hours. The number of searching events (parasitoids on the host plant) and probing events (parasitoids inserting their ovipositor to place an egg into the fruit, flower head or gall) are recorded during discrete observation periods. Afterward, the host material is isolated and held for parasitoid or fly emergence.

9. Releasing of Natural Enemies

The researchers have to receive approval for the release of parasitoids and permits for the limited release are required. Up till now, *Psyttalia lounsburyi* has been released and recovered in field-cage studies, but has not yet been shown to overwinter. More work has been done with *P. humilis*, which is easier to rear, and levels of up to 60% parasitism have been reported from cage studies (Wang et al., 2009; Yokoyama et al., 2008). However, as with *P. lounsburyi*, there is no clear evidence to date that *P. humilis* can establish and thrive without repeated augmentation.

10. Putting Natural Enemies into Services

The farmers want to identify, learn functions and interested in rearing of different natural enemies of fruit flies for their fruit or vegetable ecosystem. For field interpretation, walk, observe, and collect different natural enemies on fruits,

flowers, plants, or soils as well as on larvae, pupae or adults of fruit fly. After field walk, observe collection, sort, identify and brainstorm of different natural enemies from processing area. Allow the insects to kill by putting in alcohol and quickly sort them on white trays or plates as predator, parasitoid or pathogen. Afterward start the laboratory rearing of different natural enemies and their release into field as outlined by Shah et al., (2014), and Sarwar et al., (2015). Identify and practice the cultural practices those are helpful to conserve and encourage reproduction of natural enemies of fruit flies.

Researchers from the Department of Agriculture, Department of Food, and University currently are working to identify local and import natural enemies from abroad to control fruit fly. It is hoped that one or more parasite species can someday provide acceptable control, especially in commercial and ornamental plantings. However, suppressing fruit fly populations with biological control agents will help to reduce overall fly densities and potentially reduce the number of pesticide treatments needed in backyard, landscape or commercial orchard to achieve pest's control and it may be cost-effective.

11. Conclusion

This article describes background information on fruit fly pests and their natural enemies, identifies specific natural enemies for importation and evaluation, and for possible release into backyard, landscape, or commercial orchard. Biological control is a practical, safe and economically effective mean of fruit fly control, and its importance continues to grow in regions where pesticide use is less desirable or more restricted. The predator like birds, poultry and probably many insects consume a number of pests, particularly ants are very efficient in protecting from pests like fruit flies. So, try to increase habitats for predators, such as ants, ground beetles, spiders and birds. The insects, mostly wasps and flies lay eggs on or near fruit flies pest in orchard or vegetable production situation. Some pathogens infecting fruit flies are bacteria, virus and fungi, however, both viruses and bacteria infect their host when eaten, while fungal pathogens can infect their hosts by penetrating directly through surfaces of host's body. But the best results are gained from a combination of the predators, parasites and pathogens to manage fruit flies commonly infesting fruits and vegetables. Fruit fly is a pest that needs a community approach; it could be the perfect opportunity to meet the neighbor growers to plan a coordinated effort to aid in fruit fly's control. Over the coming years, researchers can better understand the level of controls expected from natural enemies, and improve integrated pest management (IPM) programs to integrate biological controls with the insecticides currently used in the control of fruit fly pests.

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