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An Area-wide Integrated Management of Fruit Fly (Diptera: Tephritidae) Pests in Fruits Production

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Abstract

Tephritid fruit flies (Diptera: Tephrtitidae) are the world's most devastating insect pests inflicting direct and indirect damage to fruits. Among the fruit flies, oriental fruit fly *Bactrocera dorsalis* (Hendel) and peach fruit fly *Bactrocera zonata* (Saunders) are the most important pests of fruits in some parts of world. Therefore, this paper has focused on adaptation and adoption of an Integrated Pest Management (IPM) practices for control of fruit flies among fruits growers using farmer‘s field. Most often, female fruit fly adults puncture the fruit with long and sharp ovipositor, lay their eggs in the fresh flesh and these hatch into larvae (maggots), which habitually feed on the inside of host, resulting in a soft, mushy mess. The fruit’s skin is breached, bacteria enter in puncture and the host starts to decay. If uncontrolled, fruit flies can damage up to 100 percent of some hosts resulting in millions of dollars losses in profit to the fruit production industries owing to management and eradication costs. The fruit fly’s damage causes an increase in plant yield prices and even limits produce availability, and excludes fresh produce from valuable interstate and overseas markets, leading to fewer jobs and less income for affected regions. An area-wide integrated pest management (AW-IPM) of fruit fly in a locality is a regional initiative coordinated by any organization with funding support from any state. Several methods exist to suppress fruit flies and reduce their damage; however a combination of pre and post-harvest management can give good control of fly pests. It has been shown that a pre harvest IPM combination of male annihilation technique (MAT) (using methyl eugenol as a lure) plus sanitation can bring down *B. dorsalis* and *B. zonata* infestations to lower level in any year. An additional cover spray of Deltamethrin 2.8 EC @ 0.5 ml/ l (which is half the recommended dose) plus Azadirachtin (0.03%) @ 2 ml/ l (neem based botanical) can give 100% good control in the year. Post harvest treatments especially of mango with hot water at 48°C for 60 and 75 min can result in 100% control at both the time regimes than untreated fruits exposed to gravid females (but not treated in hot water). It is hoped that the selection of structured exercises presented in this article would provide good inspirational tools to the trainers, extension personnel and farmers to create a sound scientific knowledge base for sustainable management of fruit flies in orchards.

Keywords

Bactrocera, *Dacus*, Dacinae, Tephritidae, Fruit Fly, Male Annihilation Technique, Control

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1. Introduction

Fruits are an important part of our diet and their eating provides health benefits such as offers essential nutrients, maintenance of body and reduces risk of some chronic diseases (Sarwar, 2011). Asian countries produce 178 million tons of tropical fruits which amount to 66% of the total global production and earn US$ 2.5 billion (Somsri and Vichitrananda, 2007). However, several factors such as tephritid fruit flies (Diptera: Tephrtitidae) are the world's most devastating insect pests and constrain in fruits production. The tribe Dacini with the genus *Bactrocera* contains most of the important pest species in Asia and the

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South Pacific countries. Many major pest species in this genus belong to the *Bactrocera dorsalis* (Hendel) complex, which is composed of closely related species that look very similar, but infest different host fruits and are found in different regions. Fruit flies exist in high populations in many habitats such as in native forests, fruit orchards, home gardens, housing estates and urban areas, and even one gravid (full of eggs) female fly is a threat. Fruit flies cause serious economic damage to orchards and fruit damage can rise to 100% in unprotected orchards (Sarwar et al., 2014 a; Sarwar, 2015 a).

The life cycle of the fruit fly typical undergoes complete metamorphosis that consists of four stages, namely; egg, which a female lays into fruit with a sharp pointed ovipositor and in this process may also inject fruit-rotting bacteria; larva, that feeds on fruit and undergoes three larval instars; pupa, where mature third instar larva drops into the ground, crawls usually into soil or leaf litter and develops into a pupa inside a hard shell of third instar larval skin called puparium; and adult that emerges and feeds on protein and sugar to become sexually mature and then mates. Area-wide management is an integrated pest management (IPM) applied against an entire target pest population within a delimited geographical area. This article is divided into two parts; first part provides basic information on various aspects of fruit flies and part second contains the pests control exercise guides. In addition, technical information on identification on two commonly occurring fruit fly species in orchards is included (Ekesi et al., 2006).

1.1. Fruit Flies of Economic Importance in the Genus *Bactrocera*

The two key fruit fly pests, oriental fruit fly *Bactrocera dorsalis* (Hendel) and peach fruit fly *Bactrocera zonata* (Saunders) are determined as based on their incidence in major fruits and seasonal abundance. From an economic point of view, these species mainly attack mango and guava fruits. For accurate identification of these pest species, in *B. zonata* fore wings are with costal band but either discontinuous or with an extremely narrow section distal to apex R2+3 before expanding into a spot in wing apex. In *B. dorsalis* costal band confluents with R2+3 and not expanding into a distinct spot in wing, and having black T-shaped mark on the top of the abdomen ((Riaz and Sarwar, 2014 a; Sarwar et al., 2014 b).

Fruits grown by owners for home or commercial consumptions are equally at risk to fruit flie. The end of the male fly's abdomen is blunt, whereas females have a large black ovipositor at the end of their abdomen that is visible to the naked eye. Larvae are yellowish white maggots with a pointed head. Mature larvae pupate in fruit in summer; in fall they leave the fruit and pupate in the soil under the tree. Larvae produced during late fall pupate in the soil, where they spend the winter. Although the fruit flies do not have a true diapause, their development is sufficiently slowed during the winter and pupae produced in late fall do not emerge until the following spring. Fruit flies also overwinter as larvae in fruit and to a lesser extent as adults and eggs. It is believed that at least three, possibly four, generations of fruit flies could develop in various areas. In spring, early-emerging adults lay eggs in un-harvested fruit from the previous year's crop, whereas later-emerging flies (May-June) can lay eggs directly into new fruit. Fruit flies that develop in un-harvested fruits from the previous year emerge to mate and lay eggs on the new crop (July and August) (Riaz and Sarwar, 2014 b, Sarwar and Riaz, 2014).

1.2. Damage Due to Fruit Flies

Fruit fly larvae are the main stage causing damage and feed exclusively in the fruits. Fruit fly's damage includes egg laying through sting from female flies in the fruit surface, fruits drop, or direct pulp destruction results by larvae that renders fruit useless for consumption. Larval feeding allows microorganisms to invade the fruit, causing rot and lowering fruit quality. Within processing area, to do hands-on exercise on fruit flies damage symptoms, it is important to learn how to identify species, life cycle stages, damage symptoms and degree of damage caused by fruit flies. The most common problems associated with fruit fly infestations can be described as; the fruit fly stings causing blemishes and rot, and at early stage of fruit development may results into premature fruit drops, and stung fruit is unsuitable for storage or sale (Riaz and Sarwar, 2013).

1.3. Assessment of Fruit Fly Infestation

For understanding the life cycle and damage characteristics of fruit flies to help in designing the most appropriate fruit fly management strategies in the farming communities, always examine each fruit and look for localized areas showing fruit fly's oviposition marks or fractures. Take note of characteristic damage and other related observations and separate suspected fruit fly damaged fruits from the undamaged fruits. Dissect all suspected fruit fly damaged fruits to confirm the presence of fruit fly eggs or larvae. The assessment of fly's damage should not only be done on the number or percentage of infestation, but also on the history of treatment of the orchard. By understanding the percentage of infestation in the orchard and relating this with the other conditions and treatment history of the orchard, the farmers can develop ideas for better pest management to reduce fruit fly population and build a healthier orchard.

Usually, while going to the orchard, collect 100 fresh ripe fruits randomly. The fruit sample may be taken directly from the tree or from the fresh fallen fruits on the ground. Observe the 100 samples for any external symptom of fruit fly's infestation and separate fruits into two categories: - possibly infested fruits indicated by the presence of puncture mark or other relevant signs (how many are possibly infested), and not infested (how many are not infested). Each sample from the category of possibly infested, the fruits would then be dissected as to confirm the presence of fly larvae inside and from the possibly infested how many fruits are confirmed to have larvae inside, and then count the percentage of confirmed infested fruits (number of confirmed infested fruits× 100%/ 100 samples). Compute for percentage of fruit fly damaged fruits and take note of all relevant observations and experiences during this activity.

2. Integrated Management of Fruit Flies

Management programs of fruit flies need to focus on key pests by taking into consideration their breeding activities in the farming and non-agricultural habitats. Components of control program such as the Male Annihilation Technique (MAT), legislation, use of parapheromones and baits, farm hygiene and sanitation, quarantine, surveillance and post-harvest treatment should be included (Mwatawala et al., 2009). There are several things that can be done to encourage the activities of pest control in an orchard, some common techniques used for control program of fruit flies include the following components:-

2.1. Pre-harvest Control Program of Fruit Flies

Pre-harvest managing of fruit flies points out simple but essential management tools that each grower should consider prior to the fruits are harvested. However, it does not provide a single solution to the fruit fly problem nor does it covers post-harvest treatments for export (Sarwar, 2015 a; 2015 b).

2.1.1. Cultural Control

Although the cultural methods are laborious, however these are essential and very effective against fruit flies. They include, 1) orchard sanitation, which involves removal of infested fruits, fallen or on the tree, and their destruction in an augmentation where developing parasitoids can be collected for release into the orchard, 2) mechanical protection by wrapping of the fruits, and 3) early harvesting, which can be effective for certain fruits such as mango, papaya, banana and sapodilla, as these fruits are not infested in the pre-maturity stages (Klungness et al., 2005).

2.1.2. Orchard Sanitation

It is destroying of all fallen fruits at weekly intervals in the fruit growing areas. Among others practices, crop sanitation is very practical and environment-friendly method for fruit fly management. Crop sanitations are accomplished by preventing old infested fruits lying on the ground that are acting as reservoir of fruit flies from infesting crops in the next fruiting cycle. The removal of fallen fruits or old crops each can produce a large numbers of fly adults, so, their removal and destruction is very important for IPM of fruit flies and the collected fruits should be buried upto 6 inches deep in soil. In some part of the world, good success in reducing population of fruit flies using sanitation has been achieved (Sarwar, 2015 b).

2.1.3. Mechanical Protection (Bagging or Netting) of Fruits

In this exercise, fruit bagging is the practice of covering the fruits with some sort of protective layer that prevents fruit flies from laying eggs in the fruits. Oftentimes, fruit bagging increases fruit quality and consequently also increases its selling price. The young fruits should be completely bagged and bags must not have any holes to prevent oviposition by pest. Initially this exercise is labour intensive and increases cosmetic value of fruits, however the age of bagging of different fruits varies. Various kinds of cheap bagging materials may be used and can be very effective when applied at a stage of fruit development before the fruits have become attractive to fruit flies (Sarwar, 2015 c).

2.1.4. Early Harvesting

Due to colour preferences of fruit fly for oviposition, some fruits at early stage are not host, in such cases this method could be employed e.g., the green mangos are not hosts of fruit fly. Early harvesting of fruits i.e., before fruit flies attack the fruits, is for fruit fly species that infest almost-ripe fruits, but not for species that attack small, green and un-harvestable fruits. Other cultural management options can be employed to complement crop hygiene, sanitation and fruit bagging (Sarwar, 2015 d).

Some of the other fruit flies management options include the following and the choice of any of these methods depends on location and available resources:-

2.1.5. Biological Control

Several biocontrol agents of different taxa are suitable for suppression of fruit flies. These include Hymenopteran (egg, larval and pupal) parasitoids, entomopthogenic fungi and predatory ants. The eggs, larvae, pupae and adults are main life stages in the development of fruit flies. Certain Hymenopteran parasitoids are commonly employed in

biological control of fruit flies, but these alone do not provide high degree of control on sustainable basis. For reducing the infestation of this pest in mango *Mangifera indica* L. orchards, biological control agents and the male annihilation technique have been evaluated. Significantly fewer fruits have been found infested with fruit flies in the treated blocks compared with fruits in the untreated areas. The field efficacy of the Hymenoptera larval and pupal parasitoids *Aganaspis* (*Trybliographa*) *daci* (Weld) and *Dirhinus giffardii* Silvestri, respectively, plus the male annihilation technique in controlling fruit flies has been significantly high than that of biological control agents and male annihilation applied as separate treatments. The release of parasitoids as agents of biological control can play a major role in the suppression of fruit fly populations and parasitoids also pose a minimal non-target risk (Shah et al., 2014). The egg parasitoid *Fopius arisanus* has proven to be very promising against *B. invadens* and is presently being released (Mohamed et al., 2010). Up to 40% parasitism has been recorded from the field on mango orchard. The efficacy of the entomopathogenic fungus (*Metarhizium anisopliae,* isolate) in suppressing adults and pupariating larvae of several fruit fly species in the genera *Ceratitis* and *Bactocera* has been demonstrated (Ekesi et al., 2007). The predatory weaver ant *Oecophylla longinoda* (Latreille) contributes significantly to fruit fly reduction in mango (Van Mele et al., 2007). What's more, the combining control tactics could be a very important aspect of an action plan for fruit fly population suppression (Sarwar, 2015 e).

2.1.6. Growing of Less Susceptible Varieties

Always select tree varieties or rootstocks with known insect tolerance or disease resistance because some fruits are tolerant while many rootstocks are somewhat resistant to pests. The mango cultivars Dushehari and Langra are least infested, while cultivars Banganpalli and Totapuri have a high mean infestation. Forever, know about the hardiness zone, and choose varieties that are locally adapted; winter damage resulting in bark cracking can cause a tree to be more susceptible to attack by many diseases and insects. Constantly, plant trees at root-collar depth, and in an optimal site, instead of letting the turf grow around the trees and compete for water and nutrients, and to apply a mulch around the base of trees, but keep it away from the trunk (Ekesi, 2010).

2.1.7. Use of Insecticides

As fresh mango fruits are of value both to domestic and international markets, therefore it is important to avoid insecticidal sprays close to harvest so as to obtain residue-free fruits. Normally, the insecticides are not recommended in IPM of fruit fly as there are other robust tools available, however in citrus fruits these pests can be suppressed by a single spray. It is also felt that insecticidal dose level should be reduced with exploration of safer and environment friendly insecticides. It has been found that cultural methods like orchard sanitation (collection and destruction of all fallen fruits), inter tree ploughing combined with a cover spray of Deltamethrin 2.8 EC @ 1 ml/ l can give an excellent control of fruit flies. However, it is found in subsequent investigations that male annihilation technique (MAT) using methyl eugenol as lure is a potent tool in obtaining of good control levels. The limited uses of pesticides in protein baits can give good fly's pest control (Sarwar, 2015 f).

2.1.8. Bait Sprays

Fruit flies adult need protein for their reproductive functions, in this technique fruit fly suppression is mainly based on the use of food baits (hydrolyzed proteins or their ammonium mimics) combined with a killing agent, and applied in localized spots. This method targets adult flies, mainly females, and aims at attracting and killing them before they infest fruits. The beer waste based protein baits or otherwise mixed with insecticide can be successfully used for fruit fly suppression. Weekly sprays of GF-120 Spinosad bait can provide a reasonable reduction of damage in mango (Vayssieres et al., 2009). Baiting techniques are safe to non-target beneficial, and relatively cheap in terms of product price, time and application equipment, but should not be used as a stand-alone method (Sarwar, 2015 g).

2.1.9. Male Annihilation Technique (MAT)

Male annihilation involves the deployment of high density trapping stations consisting of a male attractant combined with an insecticide. The aim of it is to decrease male fruit fly populations so drastically that mating does not occur or opportunities for mating are extremely reduced. Males of many fruit flies are attracted by one or more of certain chemical compounds called male lures. As a component of fruit fly management, lures are used to trap the male flies. For using lures, a large number of traps are needed that are excellent tools for monitoring of flies population. The best known and most use of these lures are: - 1) Methyl eugenol, chemically known as 4-allyl-1, 2-dimethoxybenzene can attract males of many *Bactrocera* species, but not members of the sub-genus *Zeugocadus,* which includes the melon fly (*B. cucurbitae*), and also *B. caudata* and *B. tau*). The methyl eugenol (e.g., from up to 500 m away) can attract male flies but not the female flies. 2) Cue lure, chemically known as 4-(p-acetoxyphenyl)-2-butanone can attract males of many *Bactrocera* and *Dacus* species. Cue lure (e.g., from up to 300 m away) can attract male flies but not the female flies. Some preliminary studies suggest that it may be possible to develop female lures, but none is commercially available at this moment. Thus, in addition to lures that only attract males,

there are food baits and other attractants to draw both sexes, usually females somewhat more than males. These include yeasts, certain bacterial odors, and hydrolyzed proteins. More recently, a yeast autolysate has been used, which is produced by enzymatic autolysis of yeast. In both the lure and protein traps, insecticide is usually mixed with the trap so that the flies can die and remain within the trap (Sarwar et al., 2015; Sarwar, 2015 h).

2.1.10. Sterile Insect Technique (SIT)

The sterile insect technique (SIT) is a form of biological control in which large numbers of sterile flies are released to flood the wild fly populations, to reduce the possibility of wild flies mating to produce fertile eggs. This technique involves mass breeding (huge quantities) of target fruit fly in insectaries and sterilizing the males by exposing them to low doses of radiation. These sterile male flies are then released by air over infested areas, where they mate with wild females. If the sterile males vastly outnumber the fertile wild males, the wild fly populations quickly die out. The proportion of infertile males to fertile wild males must be at least 10: 1. For adult releases, trials using chilled adult flies resulted in the development of a protocol that similarly maximizes emergence, flight and longevity. Chilling is useful because chilled flies are immobile, so space requirements and cost for packaging and transport are reduced. This method in some countries is good when working with a low pest population and can also be used in combination with other methods of fruit fly control (Sarwar, 2015 i; 2015 j).

Because several fruit fly species commonly co-exist in the fragmented fruit production systems, the fruit fly control program promotes an IPM approach which offers better prospects for the horticulture industry. For example, the combined application of *M. anisopliae* and food bait resulted in a huge reduction (92%) of *B. invadens* population on mango. All the listed management techniques are currently available and grower's education would be crucial for their adoption. There are some areas that are free from pest fruit flies and can be maintained free from fruit flies using area-wide integrated pest management (AW-IPM) principles. In addition to these, horticultural production, as a whole, is at risk from incursions of other pest fruit fly species. The AW-IPM of fruit flies can be practised for many years when protecting areas, which have only marginal opportunities for fruit fly establishment (Jessup et al., 2007).

2.2. Post-harvest Control Program of Fruit Flies

Effective and safe post-harvest treatments must be applied to export commodities to comply with quarantine regulations. Although there are different post-harvest dis-infestation techniques, the appropriate options include: - 1) heat treatment (e.g., for mango) and 2) cold treatment (e.g., for citrus and avocado). The necessary parameters are being developed and once available, these treatments should increase the potential of tropical fruits to reach lucrative export markets. Treatments with hot water at 48°C for 60 and 75 minutes can result in 100% control at both the time regimes that seem to have been controlled in the hot water treatment. The untreated fruits, which are also exposed to gravid females showed 5.55-30% infestation. These results would mainly pertain to mortality of eggs as oviposition period would be around 3 days, within which the treatments are administered. Fruits, which have larval feeding, tend to yellow early and become softer and therefore get culled out. Subsequent studies by the authors have shown that eggs and third instars of larval stages are heat susceptible at 48°C for 60 minutes. So, hot water treatment is ideal in support of pre export of fruits for fruit fly disinfestations (Abraham et al., 2006).

3. Conclusions

The fruit flies are the major insect pests of fruits but can be well managed by a combination of pre harvest and post harvest treatments. Pre harvest treatments alone ensure greater degree of control and it can be further subjected to post harvest treatments to satisfy global disinfestations requirement. These strategies are environment friendly and fetch residue-free produces. This case study indicates that applying of integrated management technology for fruit flies control in plant production systems can yield successful results. Efforts should be made to carry out the practice of area wide (community level) IPM application as opposed to individual orchard approach for greater adoption of combined strategy. The success of AW-IPM programmes is highly dependent on monitoring for fruit flies, appropriate and quick response to incursions, and an active participation by all growers and the rest of the community in the area under the integrated program. The AW-IPM tools for fruit fly mitigation currently in use are regional and smaller area levels methods such as trapping, trap arrays, border inspections, community awareness programs, male annihilation technique (MAT), sterile insect technique (SIT) as well as baiting and postharvest treatments.

References

[1] Abraham, V., Sreedevi, K. and Nagaraju, D. K. 2006. Pre and post-harvest IPM for the mango fruit fly, *Bactrocera dorsalis* (Hendel). Fruit Flies of Economic Importance: From Basic to Applied Knowledge. Proceedings of the 7th International Symposium on Fruit Flies of Economic Importance, 10-15 September 2006, Salvador, Brazil. p. 179-182.

[2] Ekesi, S. 2010. Development and Implementation of a Sustainable IPM Program for Major Mango Pests and Opportunity for Improving Market and Processing Information in sub-Saharan Africa. Progress Report. Deutsche Gesellschaft fur Technische Zusammenarbeit (GTZ) GmbH, Eschborn, Germany.

[3] Ekesi, S., Dimbi, S. and Maniania, N. K. 2007. The role of entomopathogenic fungi in the integrated management of tephritid fruit flies (Diptera: Tephritidae) with emphasis on species occurring in Africa. In: Ekesi, S. & N. K. Maniania (eds.) Use of Entomopathogenic Fungi in Biological Pest Management, Research, Signn Post, Kerala, India. p. 239-274.

[4] Ekesi, S., Nderitu, P. W. and Rwomushana, I. 2006. Field infestation, life history and demographic parameters of *Bactrocera invadens* Drew, Tsuruta & White, A new invasive fruit fly species in Africa. Bulletin of Entomological Research, 96: 279-386.

[5] Jessup, A. J., Dominiak, B., Woods, B., De Lima, C. P. F., Tomkins, A. and Smallridge, C. J. 2007. Area-Wide Management of Fruit Flies in Australia. Area-Wide Control of Insect Pests. p. 685-697.

[6] Klungness, L. M., Jang, E. B., Mau, F. L., Vargas, R. I., Sugano, J. S. and Fujitani, E. 2005. New sanitation techniques for controlling Tephritid fruit flies (Diptera: Tephritidae) in Hawaii. J. Applied Science Environment Management, 9: 5-14.

[7] Mohamed, S. A., Ekesi, S. Hanna, R. 2010. Old and new host-parasitoid associations: Parasitization of the invasive fruit fly *Bactrocera invadens* (Diptera: Tephritidae) and five other African fruit fly species by *Fopius arisanus*, an Asian opine parasitoid. Biocontrol Science and Technology, 10: 183-196.

[8] Mwatawala, M., De Meyer, M., Makundi, R. and Maerere, A. 2009. Design of an ecologically-based IPM program for fruit flies (Diptera: Tephritidae) in Tanzania. Bulletin of Entomological Research, 99 (6): 629-641.

[9] Riaz, M. and Sarwar, M. 2013. A New Record of Fruit Fly *Trupanea amoena* (Frauenfeld) within Genus *Trupanea* Schrank of Subfamily Tephritinae (Diptera: Tephritidae) from Pakistan. Journal of Zoological Sciences, 1 (2): 7-12.

[10] Riaz, M. and Sarwar, M. 2014 a. Fruit Fly *Tephritis zernyi* Hendel, A Member of Genus Tephritis Latreille in Family Tephritidae within Order Diptera. Journal of Agriculture and Allied Sciences, 3 (4): 17-23.

[11] Riaz, M. and Sarwar, M. 2014 b. A New Record of Safflower Fly *Acanthiophilus helianthi* (Rossi) of Genus Acanthiophilus Becker in Subfamily Tephritinae (Diptera: Tephritidae) from the Fauna of Pakistan. Journal of Agriculture and Allied Sciences, 3 (1): 39-44.

[12] Sarwar, M. 2011. Management of Banana (*Musa paradisiaca* Linnaeus) Orchard against Insect Pests. Federal Urdu University of Arts, Science and Technology Journal of Biology, 1 (1): 107-110.

[13] Sarwar, M. 2015 a. Quarantine Treatments for Mortality of Eggs and Larvae of Fruit Flies (Diptera: Tephritidae) Invading Fresh Horticulture Perishable Produces. International Journal of Animal Biology, 1 (5): 196-201.

[14] Sarwar, M. 2015 b. Cultural Measures as Management Option against Fruit Flies Pest (Tephritidae: Diptera) in Garden or Farm and Territories. International Journal of Animal Biology, 1 (5): 165-171.

[15] Sarwar, M. 2015 c. Mechanical Control Prospectus to Aid in Management of Fruit Flies and Correlated Tephritid (Diptera: Tephritidae) Pests. International Journal of Animal Biology, 1 (5): 190-195.

[16] Sarwar, M. 2015 d. How to Manage Fruit Fly (Family Tephritidae) Pests Damage on Different Plant Host Species by take up of Physical Control Measures. International Journal of Animal Biology, 1 (4): 124-129.

[17] Sarwar, M. 2015 e. Biological Control Program to Manage Fruit Fly Pests and Related Tephritids (Diptera: Tephritidae) in Backyard, Landscape and Garden. International Journal of Animal Biology, 1 (4): 118-123.

[18] Sarwar, M. 2015 f. Birth Control for Insects: The Sterile Insect Technique (SIT) for Controlling Fruit Fly (Tephritidae: Diptera) by Releasing Sterile Males. International Journal of Animal Biology, 1 (5): 253-259.

[19] Sarwar, M. 2015 g. Attraction of Female and Male Fruit Flies (Diptera: Tephritidae) to Bait Spray Applications for Reduction of Pest Populations. International Journal of Animal Biology, 1 (5): 225-230.

[20] Sarwar, M. 2015 h. The Role of Male Annihilation Technique to Get Rid of Notorious Fruit Flies (Tephritidae: Diptera) in Fruit and Vegetable Farms. International Journal of Animal Biology, 1 (5): 260-265.

[21] Sarwar, M. 2015 i. Field Tests for Exploiting the Behavioral Control Tactics to Pest Tephritid Fruit Flies (Insecta: Diptera). International Journal of Animal Biology, 1 (5): 243-248.

[22] Sarwar, M. 2015 j. Genetic Control Tactic against Fruit Flies (Diptera: Tephritidae) Insect to Escape Destruction of Perishable Horticulture Crops. International Journal of Animal Biology, 1 (5): 209-214.

[23] Sarwar, M. and Riaz, M. 2014. New Distribution Records of Fruit Fly *Dacus sphaeroidalis* (Bezzi) (Diptera: Tephritidae) From Pakistan and Improved Description of this Pest Species. Journal of Zoological Sciences, 2 (1): 1-6.

[24] Sarwar, M., Ahmad, N., Rashid, A. and Shah, S. M. M. 2015. Valuation of gamma irradiation for proficient production of parasitoids (Hymenoptera: Chalcididae & Eucoilidae) in the management of the peach fruit-fly, *Bactrocera zonata* (Saunders). International Journal of Pest Management, 61 (2): 126-134.

[25] Sarwar, M., Hamed, M., Yousaf, M. and Hussain, M. 2014 a. Surveillance on Population Dynamics and Fruits Infestation of Tephritid Fruit Flies (Diptera: Tephritidae) in Mango (*Mangifera indica* L.) Orchards of Faisalabad, Pakistan. International Journal of Scientific Research in Environmental Sciences, 2 (4): 113-119.

[26] Sarwar, M., Hamed, M., Yousaf, M. and Hussain, M. 2014 b Monitoring of Population Dynamics and Fruits Infestation of Tephritid Fruit Flies (Diptera: Tephritidae) in Guava (*Psidium guajava* L.) Orchard. Journal of Agriculture and Allied Sciences, 3 (2): 36-40.

[27] Shah, S. M. M., Ahmad, N., Sarwar, M. and Tofique, M. 2014. Rearing of *Bactrocera zonata* (Diptera: Tephritidae) for parasitoids production and managing techniques for fruit flies in mango orchards. International Journal of Tropical Insect Science, 34 (1): 108-113.

[28] Somsri, S. and Vichitrananda, S. 2007. Tropical fruit production and marketing in Thailand. Horticulture Research Institute, Department of Agriculture, Chatuchak, Bangkok, Thailand. p. 77.

[29] Van Mele, P., Vayssieres, J. F., Van Tellingen, E. and Vrolijks, J. 2007. Effects of the African weaver ant *Oecophylla longinoda* in controlling mango fruit flies (Diptera: Tephritidae) in Benin. Journal of Economic Entomology, 100: 695-701.

[30] Vayssieres, J. F., Sinzogan, A. A. C., Korie, S., Ouagoussounon, I. and Thomas-Odjo, A. 2009. Effectiveness of spinosad bait sprays (GF-120) in controlling mango-infesting fruit flies (Diptera: Tephritidae) in Benin. Journal of Economic Entomology, 102: 515-521.