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# Attraction of Female and Male Fruit Flies (Diptera: Tephritidae) to Bait Spray Applications for Reduction of Pest Populations

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## Abstract

The objective of this study is to determine the efficacy of the bait spray applications in controlling of fruit flies (Diptera: Tephritidae) on fruits and vegetables under field conditions and to make recommendations on how to move this package forward to all stakeholders. Because of concerns over damage to the environment and human health by insecticide cover sprays for fruit fly control, the bait spray technique has been developed. Bait spray applications as an "attract and kill" technology; attract both male and female fruit flies, making them more effective than the male attractant method for field pest management. Bait stations consist of an attractant, a killing agent and a device which contains both of these ingredients. Most bait sprays used in few parts of the world still rely on sugar and molasses, but in many countries the most commonly used are protein hydrolysate, acid hydrolysate and yeast autolysate. The bait speckles are discovered by the ever-foraging fruit flies as these move about the trees each day, and when the pests feed on the very small amount of organically-accepted active ingredient of an insecticide, these are killed. The categories of bait stations may be device carrying on a combination of insecticide and bait in a single formulation or device with a separated bait and insecticide. Fruit flies are lured to the bait and ingest a lethal dose of insecticide or fruit flies get in contact with a lethal dose of insecticide. Bait spray application to knock down localized fruit flies population and infestation is an important component of the pest eradication and increasing the effectiveness of the program that can be one of the most suitable alternatives. A further development and validation of bait sprays require an area-wide approach in view of fly's migration, fruit infestation and cost effectiveness. Further research is needed to optimize bait stations, the development of long-lasting attractants and killing agents, the safe use of killing agents, the development of stronger female attractants and improved bait station devices that are ideally biodegradable. As an output, bait spray alone is not a stand-alone control method for effective fruit fly suppression, but should be integrated with a series of other control methods. The stakeholders including researchers, fruits and vegetables producers and industry, and action programs are expected to contribute by facilitating research and development of fruit fly bait station technology.

## Keywords

Suppression, Bait Spray, Fruit Fly, Bait Stations, Attractant

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## 1. Introduction

Fruit flies (Diptera: Tephritidae) in the subfamily Dacinae occur throughout the tropics and subtropics of the world and cause considerable economic damage to fruit and vegetable crops. With increasing emphasis on quality of fruit and vegetable produced, and with the possibility of expansion of trade in horticultural commodities, the countries importing as well as exporting are giving increasing attention to fruit fly management at preharvest and postharvest levels (Drew, 1992). The melon fly *Bactrocera cucurbitae* (Coquillett) is

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an economically important pest of cucurbit crops. Its geographical distribution covers most countries in South East Asia and its wide host range includes many cucurbit species e.g., *Cucumis sativus* L., *Luffa acutangula* Roxb., *Momordica charantia* L., and *Cucurbita maxima* Duch (Allwood et al., 1999; Sarwar, 2014 a; 2014 b; Sarwar et al., 2013). The oriental fruit fly *Bactrocera dorsalis* (Hendel) is a tropical species that has been introduced through trade, is known to attack over 230 fruits and vegetables (USDA-APHIS, 1989). The peach fruit fly *Bactrocera zonata* (Saunders), is also an important pest species damaging orchard plants, for example guava (Sarwar, 2006 a; 2006 b; Sarwar et al., 2014 a), ber (Sarwar, 2006 c), citrus (Sarwar et al., 2014 b) and mango (Sarwar et al., 2014 c), with other host plants almost similar to those of *B. dorsalis*.

Due to fruit flies concerns, farmers cannot be able to grow fruits and vegetables without regular sprays of insecticides, valuable commercial industries can lose their clean and green advantage of produces, and this may adversely affect trade and consequently rural and regional economies.

Bait sprays containing a proteinaceous substance and an insecticide have been used to control several species of tephritid flies (Peck and McQuate, 2000; Moreno et al., 2001). In concept, the proteinaceous substance should attract tephritid adults to bait spray droplets, followed by ingestion of bait along with a toxic dose of insecticide. In principle, the attractiveness of bait spray droplets should permit a reduction in the proportion of crop or land area receiving spray as well as a reduction in the amount of insecticide needed for control compared with broadcast application of insecticide in conventional sprays (Ronald et al., 2003). However, it is highly recommended that the attractant should be female-biased, although there are powerful male specific attractants and their effects in suppressing male populations has little effect on the overall fruit infestation when used in bait stations for control purposes. The killing agent can be contact, consumable or pathogenic. This agent can also be fast acting or slow acting, including by autodissemination (IAEA, 2009). Good control with protein bait sprays is attained in an integrated pest management (IPM) program (Sabine, 1992). The bait system is recognized as an integral component of IPM in horticultural crops, because it reduces pesticide levels resulting with beneficial result for predators, parasitoids and pollinators. Protein bait applications are also less time consuming and less demanding of labor (Smith and Nannan, 1988; Sabine, 1992).

## 2. Protein Bait Sprays

The bait is a mixture of a yeast or protein extract that attracts fruit flies, and a dilute solution of an insecticide, which kills the flies once attracted to the bait. The two ingredients are diluted with water (2 percent protein solids plus 1 percent insecticide). Fruit flies shelter in shady vegetation such as fruit trees, ornamental trees and shrubs. Bait is applied in 100 ml doses into foliage, at the rate of 100 spots per hectare (6 to 8 spots per residential property). This ensures that a baited spot is within the daily wandering range of each fly within the treatment area. The use of bait sprays reduces costs and usage of insecticides, and minimizes disturbance to stakeholders. Bait attractancy is tested by placing a cardboard funnel trap (0.5 m diameter), coated with parafin wax, under treated areas of angled luffa. A plastic basket (30 cm in diameter) is placed at the base of the funnel and a plastic tube containing 5% formalin is inserted into the base of the basket and the tube is buried 7 cm deep into the ground.

## 3. Protein Bait Sprays for Control of Fruit Flies

The bait sprays comprise an attractant and a toxicant, the bait or attractant is usually a molasses or sugar solution and the toxicant is usually a stomach poison such as lead arsenate or Paris green in earlier era. Subsequent developments tended to focus on the insecticide component of bait sprays and the bait component is nearly always sugar and molasses. This approach changed on the use of protein hydrolysate as an attractant for bait sprays until when the acid hydrolysate component of bait sprays is replaced with a yeast autolysate. The protein bait acts as a food attractant and its effectiveness relies on the fact that immature females need a protein meal for developing mature eggs. The bait spray residue on the foliage is ingested by the flies and kills them. Because the bait spray relies on its attractant properties for its mode of action, overall coverage of the tree canopy is unnecessary and a 'spot spraying technique' is adequate. Experiments and experience indicate that bait spraying is most effective in 'area' treatment programs. It is ideal for medium to large orchards or where adjacent properties use the attractant technique. The method has been used to control fruit fly in the major citrus growing areas and is now being used as one component of quality assurance schemes for export produce, for example, it is being used as a field control method for mangoes grown. Similarly, protein bait sprays have been included in quarantine protocols for the export of eggplant, some chilies, watermelons and breadfruit.

Most bait sprays used in many parts of the world still rely on acid hydrolysates for their protein source, but in few countries the most commonly used protein now is a yeast autolysate produced by enzymatic autolysis. The protein hydrolysate used previously is manufactured by hydrolyzing a plant protein with hydrochloric acid. This resulted in

protein bait with a low pH. Excess acid is neutralized with sodium hydroxide leaving a salt residue in the bait. Applications of this type of bait spray often cause burning of fruit and foliage. There is minimal salt in the yeast autolysate used now so problems of phytotoxicity do not normally arise. The yeast autolysate produced is a light brown liquid, containing 420 g per liter of protein. A plant converts waste yeast into protein autolysate through a process of heating and the addition of the enzyme papain and the food preservative potassium sorbate (McQuate, 2009; McQuate et al., 2005; Solomon et al., 2012; 2014).

# 4. Advantages and Disadvantage of Protein Bait Sprays

The major disadvantage of protein bait sprays is that control may not be totally adequate at times of extreme pest pressure, especially if re-invasion of the treated area is continuous, and where the treated area is small in relation to untreated surrounding areas. Control may also be less effective as the season progresses and populations with females at all stages of sexual maturity develop. Studies have shown that gravid female fruit flies are less interested in food than in finding suitable egg-laying sites. Additionally, in areas or during periods of high rainfall, significant amounts of bait solution may be washed off from tree leaves.

On the other hand, the advantages of protein bait sprays far outweigh the disadvantages. Protein bait sprays are less harmful to beneficial insects, so, making them suitable for use in IPM programs. Because of the spot spraying technique, there is less insecticide applied to the crop or tree and non-target species have more refuges. Costs are considerably lower as less material is used per tree or per hectare. In addition, spot spraying is less time consuming than for cover spraying and therefore less demanding of labor. Farmers may also be able to use simple, inexpensive spraying equipment. Bait sprays are more environmentally sound because of reduced pesticide usage and less risk of spray drift. Spray applications can be directed on to foliage and away from fruit to minimize fruit residue problems. Reduced pesticide usage and use of coarse sprays at low pressure result in fewer hazards to the spray operator.

# 5. Fruit Fly Bait Preparation and Application

There are very few methods of application that a tree or fruit grower must learn in a lifetime. This approach has been rapidly accepted, but many growers are asking how to build a sprayer and apply the bait. Both operations are less complex than most of the mechanical work and application growers frequently can do that. Below is an effort to describe the bait sprayer and how to use it:-

## 5.1. Construction of the Bait Applicator

An auxiliary sprayer with 12 volt pump, either 45 or 60 pounds per square inch can work, with usually about 12 to 15 gallon capacity. Actually, there are many ways to configure this boom sprayer. The important factors those must include are the ability to change the angle of the spray stream so that can adjust to different tree sizes and row widths, and the ability to use a Disc style nozzle tip (D-2, D-1.5 or D-1) and a valve to allow either side to be turned off while operator covers the outside row. The example will use two adjustable angle single swivel nozzle bodies. It is better to use one double swivel nozzle body, as it is not important to separate the nozzles on the boom. The bait mixture stream shoots 15-22 feet, starting near the middle of the drive row just does not matter. There is also need a heavy duty 12 volt switch that can attach on handle bar, so that an operator can turn off the sprayer while turning at row ends, also needed some wire to splice into the switch wire on the sprayer, and clips need to securely connect the sprayer's power lead to battery.

## 5.2. Formulation of Bait Sprays

The following formulation of bait sprays is recommended for use and to mix the product outside of the sprayer, or else the bait can remain in a "blob" at the bottom of tank if added directly without mixing:-

Mix: 50 ml of yeast autolysate concentrate, 4 ml of malathion , 50% emulsifiable concentrate.

Add: enough water (946 ml) to make up one liter of solution.

About 50 ml of bait solution is sprayed on the undersurface of 1 m² of leaves on each tree. Every tree in and surrounding the orchard or village is sprayed. In vegetable gardens, such as capsicum and chilies, or cucurbit crops, 20-25 liters per hectare are sprayed as a band of coarse spray on the foliage of every third row. Sprays are repeated every seven days, starting one month before fruits mature. In some situations, protein bait spraying should be commenced soon after fruit set (e.g., capsicums and chilies) or as soon as fruits become susceptible (e.g., carambola). In very rainy areas, the spray interval should be decreased to every five days. To overcome the problem of bait being washed off from leaves and to improve the effectiveness of bait sprays, there is a new formulation, with fipronil instead of malathion and an additive that forms a gel that sticks to tree leaves and resists against rain.

## 6. Fruit Fly Bait as a Suppression Tool

The efficacy of protein bait and yeast bait to control *B. cucurbitae* and *B. tau* (Walker) infestations in angled luffa and bitter gourd has been tested. The *Bactrocera diversa* (Coquillett) is the only species found infesting flowers of angled luffa and none is found on bitter gourd. The angled luffa plot treated with protein bait and bitter gourd plots treated with either protein bait or yeast bait has considerably lower percent infested fruits when compared with the untreated plots. Yields obtained in the angled luffa plot treated with protein bait have been 81.57% higher than in the untreated plot and in the bitter gourd plots treated with either protein bait or yeast bait, increased yields remained 67.22% and 59.98% higher, respectively, than in the untreated plot. The *B. cucurbitae* and *B. tau* are the only two species that infested fruits of both crops. Among dead fruit flies feeding on the poison baits, collected from funnel traps, *B. cucurbitae* and *B. tau* are the most common species (Chinajariyawong et al., 2003).

The use of toxic protein bait sprays to suppress melon fly *B. cucurbitae*, populations typically involves application to vegetation bordering agricultural host areas where the adults seek shelter or roost. Although bait spray applications for suppression of oriental fruit fly *B. dorsalis*, populations have traditionally been applied to the host crop, rather than to crop borders, roosting by oriental fruit flies in borders of some crop species, such as papaya *Carica papaya* L. (Brassicales: Caricaceae), suggests that bait spray applications to crop borders could also help in suppression of *B. dorsalis* populations (McQuate and Roger, 2007).

Efficacy tests have been conducted using spray equipment that applies ultralow application rates of malathion NU-LURE or GF-120 spinosad by ground into citrus. Trapit Dome traps located in fields treated with malathion NU-LURE and GF-120 spinosad caught significantly fewer Mexican fruit fly *Anastrepha ludens* (Loew) than the control in all replications. Treatments reduced the Mexican fruit fly populations by 99.1 and 92.5% with malathion and 98.2 and 89.9% with GF-120 spinosad high rate. Traps in plots with lower rates of GF-120 reduced fly populations by 76.3 and 74.3% in winter and summer test, respectively. There is no indication of fly repulsion from either malathion or GF-120 spinosad during this test. The bait spray option using ground spray equipment to apply ultra-low rates of either malathion NU-LURE or GF-120 spinosad high rate is a viable cost effective treatment method to treat small acreages for *A. ludens*. For organic growers, the ground spray equipment is effective in applying GF-120 spinosad at the labeled rates (Conway and Forrester, 2011).

In studies carried out on field-caged non-fruiting host trees, effects of environmental and adult physiological and experiential state factors on responses of released Mediterranean fruit flies *Ceratitis capitata* (Wiedemann), to droplets of proteinaceous bait (PIB-7) with or without 20% insecticide (malathion) have been examined. The fresh PIB-7 is both attractive and phagostimulatory to protein deprived medflies and found that presence of 20% malathion ultra low volume concentrate (ULVC) in PIB-7 droplets does not significantly repel medflies from approaching droplets but does significantly deter feeding on them. A single relatively fresh deposit of bird feces, an important source of protein for medflies in natural environments, attracted several times more laboratory-cultured and wild medflies than 20 droplets of 80% PIB-7/20% malathion ULVC (about the average number of droplets per $m^2$ of plant canopy in aerial bait spray programs). Attraction to protein is significantly greater among wild medflies deprived of protein continuously from eclosion than among wild medflies that have recent (within 3 days) or continuous access to protein. Attraction to protein increased significantly with increasing age (2, 7 and 12 days) of protein-deprived wild medflies. It is conclude that the effectiveness of aerial bait sprays against medflies might be enhanced substantially and the proportion of infested area treated with bait spray is reduced considerably by (1) including synthetic equivalents of attractive components of bird feces in the spray mixture, and (2) adjusting spatial and temporal patterns of bait spray applications according to estimates of the composition and abundance of natural medfly food and the age structure of medfly adult populations in infested regions (Prokopy et al., 2011).

Fruit flies can be detected by catching adult flies in a grid of traps maintained within fruit growing areas and by members of the public who find larvae in fruit either from backyard trees or bought from a shop. When adults or larvae (maggots) are found, contact the local office or allow access to personal land property or staff that is carrying out fruit fly operations. Pick up fallen fruit, wrap it in a plastic bag and leave the bag in the sun for three days to kill any larvae and then put it in the garbage bin. When travelling, do not bring fruit beyond the warning signs and spread the information to incoming travellers. Also, advise to visitors not to bring fruits that may be infested when they come to visit a new locality. Because protein bait sprays are more environmentally sound and less harmful to beneficial insects, so, farmers may be able to use it as a part of IPM program (Sarwar, 2004; 2012; 2013; 2015 a; 2015 b).

## 7. Conclusion

An economic and practical fruit fly suppression tool is

needed to replace conventional aerial and ground sprays applications over human settlements, natural areas, and difficult to access areas where fruit fly hosts exist. This has been a major demand as a component for an area-wide integrated pest management action programs. During recent years, in certain areas, most conventional insecticides used to control fruit pests have been disqualified, therefore areas producing fruits and vegetables as organic farming or even fruit and vegetable for markets that request low insecticide residues, are seeking for a more economic fruit fly control option with bait sprays. To address these requirements, bait sprays can be one of the most suitable alternatives. The development of these devices needs to take into consideration cost-effectiveness, long lasting attractants and killing agents, and should target female fruit flies as well. Recent developments of synthetic food attractants and long-lasting formulations open the possibility to improve the existent baits stations or develop new ones. With both types of baits i.e., protein and yeast, it can be effectively control the infestations of *B. cucurbitae, B. dorsalis* and *B. zonata* which are severely damaging to fruits and vegetables. It is likely that these baits could also be effective in managing infestations of fruit flies in other several tropical crops. Establishment of preferred roosting hosts as crop borders may help to improve suppression of many fruit fly species by providing sites for bait spray applications. Further research is needed to assess the use of vegetation bordering or other host crops as roosting hosts, especially for oriental fruit fly. But, cost-benefit analysis is a critical component for determining the feasibility for adoption of any bait station.

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