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Management of fruit flies through traps and attractants- A review

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Abstract: The fruit flies are pests of international importance that are difficult to manage as they are polyphagous, multivoltine and have high mobility and fecundity. Only adults are exposed, while eggs and maggots remain protected in the host tissues and pupae are in the soil. Thus most insecticidal treatments are ineffective. The stage of the pest that can be targeted is the adult insect. Keeping this in view and the seriousness of the problem, the review work was conducted on different aspects of management of fruit flies with particular reference to trapping. Various trapping strategies *viz.,* bait sprays, traps and lures have been discussed along with the bait composition used by different workers.

Key words: Atrtractives, Cucurbits, Fruitfly, Traps

Introduction

Fruit flies are pests of quarantine importance and are difficult to control. They have great impact on Agri or Horti or Forest ecosystem and cause enormous damage to fruits and vegetables. Out of nearly 4,400 species of fruit flies described so far and distributed throughout the world (Norrbom, 2004), 250 species are of economic importance and are distributed widely in temperate and sub-tropical regions of the world, with the greatest diversity of species occurring in the tropical regions (Norrbom *et al.,* 1998). More than 200 species of fruit flies have been reported from India, however, majority of them have no economic importance (Madhura and Verghese, 2003). The major economically important species of fruit flies are *Bactrocera dorsalis* (Hendel), *Bactrocera cucurbitae* Coquillent, *Bactrocera zonata* (Saunders) and *Bactrocera correcta* Bezzi. Among these, *B. dorsalis, B. zonata* and *B. correcta* infest mango and guava and *B. cucurbitae* infests cucurbitaceous vegetables (Nath and Bhushan, 2006).

B. tau was reported on many fruits and vegetable crops in India by Narayanan and Batra (1960). This species was reported as a serious pest of cucurbitaceous vegetables (Sharma and Bhalla, 1964; Verma, 1985). Kapoor *et al.* (1980) reported 34 species belonging to the genus *Bactrocera* from India out of which *B. cucurbitae* (Coquillett)*, B. zonata* (Saunders) and *B. dorsalis* (Hendel) occur as serious pests, inflicting annual loss running in crores of rupees in India (Agarwal and Kapoor, 1986). Fruit flies, *Bactrocera* spp. are the major limiting factors in successful cultivation of guava causing almost 100 per cent damage during rainy season (Singh and Sharma, 2013) as it is the most preferred host of fruit flies.

The attack of fruit flies reduces fruit yield and quality, besides rendering them vulnerable to secondary infections. Several workers have studied the biology of the fruit flies. The flies infest the fruits by inserting ovipositor and laying eggs beneath the skin. The maggots develop inside the fruits and eventually drill their way out for pupation in the soil and emerge as winged adult to begin the life cycle.

Trapping strategies

The fruit flies are difficult to control since egg-laying is in the ripening fruits and tender vegetables, and maggots develop inside, which are out of the reach to insecticides. The management tactics should be concentrated mainly in the pre-oviposition stage when the flies require plenty of water to drink and proteins for egg maturation, hence are easily attracted to solution or syrup. This habit of the flies has been taken advantage to poison their food and such efforts of various workers are reviewed here under:

1. Baits

After emergence, the adults need to feed regularly on carbohydrates and water to survive and the females require proteinaceous materials for the development of their gonads (Bateman, 1972; Fletcher, 1987). Fruit flies can be controlled by using a mixture of insecticide and food attractants, commonly known as insecticide bait sprays. This method aims to provide an effective management but food source is poisoned so that the flies are killed when they come in contact or feed on the bait.

Cornelius *et al.* (2000) reported that liquid hydrolysed proteinaceous bait (Nulure) attracted more female oriental fruit flies in guava orchard as compared to several ammonia based olfactory lures. Protein as an important component (in food baits commercial lures) to attract females of many fruit fly species has been previously documented with *B. cucurbitae* (Steiner, 1952; Narayanan and Batra, 1960; Vijaysegaran, 1985; Satpathy and Samarjit Rai, 2002 and Fabre *et al.,* 2003 and *B. dorsalis* (Steiner, 1952 and Alyokhin *et al.,* 2000).

Thomas *et al.* (2001) observed that open bottom plastic traps baited with two component synthetic lure (ammonium acetate and putrescene) caught more flies than Mcphail traps baited with Torula yeast. Fabre *et al.* (2003) reported that Solbait (protein hydrolysate) was the most effective in capturing females of melon fly. Katsoyannos and Papadopoulos (2004) reported that spheres baited with three components of food attractant containing ammonium acetate, putrescene and trimethylamine were most attractive to female *C. capitata.*

Among the various protein baits tested, yeast, soybean, fruit fly diet, protein and casein were more female selective. When total fruit flies were considered, soybean + sugar + banana was the most superior protein bait with a fruit fly capture of 4.5/trap/week in guava, while casein + sugar + papaya attracted more female fruit flies with a mean capture of 4.33 in mango (Rajitha, 2004). Fruit fly diet + sugar + banana was the most superior protein bait with fruit fly capture of 8.00 fruit flies/trap/week in guava and 6.50 fruit flies/trap/week in mango. Ammonium acetate when used at 5 per cent of the bait mixture attracted more females (Ravikumar, 2005).

Studies were made by Ravikumar and Viraktamath (2007) on attraction of female fruit flies to different protein food baits. Food bait containing proteinex and 5 per cent ammonium acetate attracted significantly more *B. correcta, B. dorsalis, B. cucurbitae* and total fruit flies (16.84 fruit flies/trap/week) in guava. While in mango, fruit fly diet and mango pulp combined with 5 per cent ammonium acetate were attractive to *B. dorsalis, B. cucurbitae* and total fruit flies (10.63 and 8.88 total fruit flies/ trap/week, respectively). Among different traps, banana based poison bait trap containing banana (1 kg) + carbofuron (10 g) + yeast (10 g) + citric acid (5 g) consistently showed significant superiority in terms of higher catches of fruit fly throughout the cropping season (Pandey *et al.,* 2010).

A lot of research work has been done by various workers for the development of most effective baits for the fruit flies using different combinations of substances ranging from fruit juices, molasses, sugar and protein hydrolysates, protein baits which is summarized in Table 1.

Table 1. Baits of fruit flies

Composition of poison bait	Fruit fly species	Author (s)
Coarse flour (middlings) 5 kg borax, 5 kg, water (90 L)	*B. oleae*	Bouhelier *et al.,* 1935
Wheat pollard (0.34 kg), olasses (0.11 kg), borase (0.11 kg), disodium hydrogen arsenite (0.01 kg), water (4.73 L)	*A. fraterculus, C. capitita*	Hayward, 1941
Wheat bran (0.23 kg), commercial borax (0.23 kg) water (4.5 L)	*Dacus ferrugineus*	Pruthi, 1940
1% molasses, 0.02% fenvalerate	*B. tau*	Saikia and Dutta, 1997
Jaggery, 0.1% dichlorvos	*B. tau*	Sood and Nath, 1998
Hydrolysed proteinaceous ((Nulure)	*B. dorsalis*	Cornelius *et al.,* 2000
Solbait (protein hydrolysate)	*B.cucurbitae*	Fabre *et al.,* 2003
Sugar and ICN enzymatic yeast hydrolysate (3:1)	*B.dorsalis* and *B.cucurbitae*	Vargas and Prokopy, 2006
Protein hydrolyzate attractants (Agricince, Amaden, BioProx OL 4N, Buminal, Norlan AMPL, Glan AMD Agrinal, and Pro-Lure Plus) at 5% concentration + 0.5 % malathion (EC).	*Ceratitis capitata (Wied.)* and *Bactrocera zonata (Saund.)*	Moustafa, 2009
Proteinex + 5% ammonium acetate	*B. correcta, B. dorsalis, B.* cucurbitae	Ravikumar and Viraktamath, 2007
Banana (1 kg) + carbofuron (10 g) + yeast (10 g) + citric acid (5 g).	*B.* spp.	Pandey *et al.,* 2010

2. Baits mixtures with commercial insecticides

Protein hydrolysate contains certain nutrients, among several amino acids, necessary for the fruit fly growth. Therefore, its use in baits reduces the amount of insecticide needed, lowers contamination and increases the protection of natural enemies (Hagen, 1955). The composition of different baits containing protein hydrolysate with commercial insecticides is presented in Table 2.

Steiner (1952) observed an average reduction of 87 to 94 per cent of larvae when a bait spray containing protein hydrolysate, sugar and parathion was done at 3 weeks interval against *B. dorsalis,* in semi-isolated orchards of guava in Hawaii. A weekly spray of 0.45 kg of 25 per cent malathion WP and 0.22 kg of yeast protein/acre was recommended by Steiner (1955) to remove the serious threat to the commercial production of passion fruit, *Passiflora edulis* Sins., in Hawaii from *B. dorsalis* and *B. cucurbitae.*

In India, a preliminary trial of bait spray containing 0.02 kg protein hydrolysate, 0.02 kg brown sugar and 0.007 kg 60 per cent malathion EC in 4.5 l of water @ 2.25 litre spray per tree was found to be quite effective in checking oviposition of *B. dorsalis* in mango fruits in Saharanpur, Uttar Pradesh (Gupta, 1958). In tests on control of *B. cucurbitae* in China, 25 per cent malathion WP at a dilution of 1:400 with protein hydrolysate as an attractant gave good control when sprayed weekly (Chen, 1960). In Kerala, to control without the risk of poisoning or phytotoxicity, a coarse spray of a liquid bait containing 1 per cent yeast protein and 0.1 per cent malathion was recommended by Dale and Nair (1966).

To suppress *Bactrocera oleae* Gmel population effectively in the mediterranean basin, Nadel (1966) recommended the aerial application of a bait containing protein hydrolysate (Zitan 85) 220 ml and 110 ml of malathion 50 EC in 1 litre water per 0.1 hectare. Combinations of undiluted protein insecticide bait no. 7 (PIB-7) with either technical malathion or naled were applied as droplets from a hypodermic syringe (spot treatment) to guava foliage in Oahu, Hawaii to control *B. dorsalis,* and *C. capitata,* and naled was found to cause greater initial mortality whereas, malathion had a greater long term effect making it more suitable to reduce economic losses to fruit crops. Ratio of 1:4 for toxicant malathion to PIB 7 was found most effective (Harris *et al.,* 1971).

Laxmanan *et al.* (1973) observed that 1 % methyl eugenol + 0.1 % carbaryl gave effective control. Abbas and Srivastava (1989) reported that fruit flies in mango can be controlled by hanging pheromone traps with 0.1 % methyl eugenol + 0.1 % malathion from April to June and suggested that about 10 traps are sufficient for a hectare.

Table 2. The composition of different baits with commercial insecticides

Composition of poison bait	Fruit fly species	Author (s)
Protein hydrolysate, sugar and parathion 0.45 kg of 25% malathion	*B. dorsalis* and	Steiner, 1952
WP and 0.22 kg of yeast protein/acre	*B. cucurbitae*	Steiner, 1955
0.02 kg protein hydrolysate, 0.02 kg brown sugar and 0.007 kg 60 % malathion EC in 4.5 L of water	*B. dorsalis*	Gupta, 1958
25% malathion WP at a dilution of 1:400 with protein hydrolysate	*B. cucurbitae*	Chen, 1960
Protein hydrolysate bait @ 220 ml and 55 ml of malathion 50 EC per 0.1 ha	*B. oleae*	Nadel, 1966
1% yeast protein and 0.1 % malathion	*B. cucurbitae*	Dale and Nair, 1966
PIB-7 (undiluted) and technical malathion/naled	*B. elorsolin B. cucurbitae C. copitata*	Harris *et al.,* 1971
SIB-7 and malathion 50% WP	*B. tryoni*	Bateman, 1973
Protein hydrolysate – malathion bait	*B. cucurbitae*	Iwahashi *et al.,* 1976
Fenitrothion (0.025%) protein hydrolysate (0.25%) or molasses (0.5%)	*B. cucurbitae*	Gupta and Verma, 1982
protein hydrolysate:water (1:50)	fruit fly	Tamori and Iraha (1986)
Yeast autolysate 1% - chloropyrifos 0.2%	*B. tryoni*	Smith and Nannan, 1988
Yeast hydrolysate and molasses (9:1)	*B. cucurbitae*	Liu and Chen, 1995
Fenvalerate (0.05%) with protein hydrolysate(protinex 0.15%) and fenthion (0.01%) with proteinhydrolysate (protinex 0.15%)	*B. dorsalis*	Mann, 1996
Nine per cent nulure + borax	*Anastrepha* spp. and *C. capitata.*	Boscan *et al.,* 2001
Molasses + malathion and water (1: 0.1: 100)	*Bactrocera cucurbitae* Coq.	Akhtaruzzaman *et al.,* 2000
Banana poison bait: 1 kg rotten banana + 10 g carbofuran + 5 g yeast + 5 g citric acid	*Bactrocera cucurbitae* Coq.	Pandey *et al.,* 2008
Spinosad and dipterex.	*Melon fly, Bactrocera Cucurbitae* Coq.	Gogi *et al.,* 2007
Methyl eugenol and malathion	*B.* spp.	Singh *et al.*, 2008
Protein hydrolyzate attractants (Agricince, Amaden, BioProx OL 4N, Buminal, Norlan AMPL, Glan AMD Agrinal, and Pro-Lure Plus) at 5% concentration	*Ceratitis capitata* (Wied.) and *Bactrocera zonata* (Saund.)	Moustafa, 2009
Methyl eugenol 0.1% + carbaryl 50 WP 0.2%	*B. dorsalis*	Singh *et al.,* 2009
Naled mix (Lambada, Lebaycid, Sumithion, commercial Malathion (2:3)	*B. zonata*	Ghanim *et al.,* 2010

A successful campaign conducted against Queensland fruit fly *B. tryoni* (Froggatt) in Easter Island, Chile by Bateman (1973) involved a first phase of bait spray consisting of Staley's Insecticide Bait No. 7 (SIB 7) mixed with malathion 50 per cent WP followed by a second phase of male anihilation through male attranctant "cuelure" 4-(p-acetoxyphenyl butane-2-one, mixed with technical malathion absorbed on to pieces of thick cotton string 25 cm long and distributed on all standing vegetation at a rate of 30/hectare. Fly population declined rapidly soon after treatments commenced and fruit infestation ceased within five weeks. Another eradication of from Kume Island, Japan was brought about by first reducing the fly population by application of protein hydrolysate-malathion bait sprays from June 1974 to January, 1975, sixteen times at fortnightly intervals followed by male annihilation. This reduced the fly population to 5 per cent of peak density which was thus eliminated by sterile fly release method by August, 1976 (Iwahashi *et al.,* 1976).

Gupta and Verma (1978) reported that fenthion (0.025%) in combination with protein hydrolysate (0.25%) reduced the damage to the extent of 8.7% as against to 43.3 % damage in untreated control. The protein hydrolysate preparations (food attractants) were previously used as bait in McPhail traps (Steyskal, 1977) and they captured a large number of both males and females of PFF and MFF (Anonymous, 1985 and Saafan, 2005).

Tamori and Iraha (1986) investigated the most suitable dilutions of protein hydrolysate for attracting adults of in field studies in Japan and found that baits in the ratio of 1:50 (protein hydrolysate:water) proved to be best. Weekly bait sprays of 1% yeast autolysate and 0.2% chlorpyrifos for 8 months in 8 ha passion fruit orchard in Queensland reduced *B. cucurbitae* infestation to near zero, as against 75% fruit damage in adjoining orchards (Smith and Nannan, 1988). Khan *et al.* (1989) reported the control of fruit fly by using the trap crops, pheromone traps and chemicals cypermethrin and malathion. Yeast hydrolysate and molasses when mixed in 9:1 ratio, increased the attractiveness to 84.2 and 81.2 per cent for females and males, respectively, as against the individual attractiveness of yeast hydrolysate (71.9 and 80.4 % for females and males, respectively) and molasses (69.4 and 78.2%) for adults (Liu and Chen, 1995).

Later in field trials in Haryana, Gupta and Verma (1982) found lowest rate of infestation by in plots sprayed with fenitrothion (0.025%), protein hydrolysate (0.25%) or molasses (0.5%), which was significantly more effective than the recommended bait spray of malathion (0.25%) and gur (0.5%). Mann (1996) also reported that fenvalerate (0.05%) or fenthion (0.01%) with protein hydrolysate (Protinex 0.15%) sprayed five times at weekly intervals was most effective in checking oriental fruit fly incidence on guava in Punjab.

Boscan *et al.* (2001) observed that nine per cent nulure + borax was effective in capturing *Anastrepha* spp. and *C. capitata*. Sar *et al.* (2001) reported that protein bait spraying reduced the amount of infestation due to *Bactrocera fraunfeldi* (Schiner) in carambola from 98 per cent to 1 per cent. Sunandita and Gupta (2001) reported that bait mixtures consisting of boric acid and protein hydrolysate caused 80 per cent mortality of *B. tau* at 10 and 12 per cent concentrations of the toxicant.

Roger *et al*. (2002) determined the attraction and feeding propensity of Mediterranean fruit fly, *Ceratitis capitata* (Wiedemann), to different protein bait mixtures with and without the insecticides malathion, spinosad, and phloxine B. Protein baits were more attractive to females than to males. Protein-starved females responded more than protein-fed females. The type of protein (USB yeast hydrolysate enzymatic, Mazoferm E802, Nu-Lure insect bait, or Provesta 621 autolyzed yeast extract) in the bait had a major influence on *C. capitata attraction, which was strongest to fresh Provesta. Aged baits* (four day-old) were not as attractive as fresh baits. In feeding propensity studies, highest response was observed for USB protein. On the basis of attraction and feeding responses Provesta (attraction and feeding) and USB (feeding) outperformed the standard Nu-Lure. Protein-starved flies were much more likely to feed on protein compared to protein-fed flies. For protein-starved flies, a mixture of Provesta and malathion repelled fruit flies, compared to a mixture of Provesta and spinosad or phloxine B. This was not the case with protein–fed flies. The wasp *Fopius arisanus* (Sonan), one of the primary natural enemies of *C. capitata,* could not consume protein baits. These studies suggest that spinosad or phloxine B, with low contact toxicity, mixed with protein baits offers a more environmentally friendly choice for control of *C. capitata* and conservation of *F. arisanus,* whereby the non target effects of broad spectrum contact poisons such as malathion can be avoided. Presumably, due to greater selectivity with spinosad and phloxine B bait treatments, the host would be killed, but not the natural enemy.

Provesta outperformed the standard Nu-Lure in attractiveness to *C. capitata* flies. Field studies in Hawaii further suggested that Provesta and Mazoferm could be used in bait sprays for suppression of *B. dorsalis* in guava orchards (McQuate *et al.,* 1999) and *C. capitata* in coffee fields (Peck and McQuate, 2000), respectively.

The application of molasses + malathion and water (in ratio of 1: 0.1: 100) provided good control of melon fruit fly (Akhtaruzzaman *et al.,* 2000). Satpathy and Samarjit Rai (2002) reported that bait containing pulp of over ripe banana (1kg), carbofuron (10 g) + citric acid (1 g) was found to be the best in luring the melon fruit fly*, B. cucurbitae* during its peak activity period. Vargas *et al.* (2003) suggested that type of protein influenced attraction of flies to the baits. The insecticides used in MAT are generally organophosphorus compounds, such as Naled, Malathion, and Dichlorvos (DDVP) (Vargas *et al.,* 2003).

Studies were made by Vargas and Prokopy (2006) to determine attraction and feeding propensity of oriental fruit fly, *B. dorsalis,* and melon fly*, B. cucurbitae* to different protein bait mixtures with and without the insecticides spinosad and malathion. The type of protein bait (Provesta ® 621autolyzed yeast extract, Mazoferm ® E 802, GF-120 ® fruit fly bait, or Nu-Lure ® Insect Bait) had a major influence on *B. dorsalis* and *B. cucurbitae* attraction and feeding, which was strongest to fresh Provesta, GF-120, and Mazoferm. There was no significant response to bait aged for 4 d. In feeding propensity studies, highest response was observed for Mazoferm. On the basis of attraction and feeding responses Provesta (attraction) and Mazoferm (feeding) outperformed the standard Nu-Lure. A mixture of Provesta and malathion was significantly less attractive to *B. dorsalis* and *B. cucurbitae,* compared to a mixture of Provesta and spinosad.

The ply board blocks impregnated in ethanol solvent, methyl eugenol and malathion have also been reported effective against fruit flies in orchards by other workers (Patel *et al.,* 2005; Stonehouse *et al.,* 2007 and Singh *et al.,* 2008). The treatments screened against fruit fly infestation, NSKE + banana based poison bait was found most effective in reducing bitter gourd fruit damage by cucurbit fruit fly during 2006, 2007 and after their average (Pandey *et al.,* 2008). Catches of MFF and PFF by olfactory stimulants in attractant traps can be used to monitoring their populations and for predicting the infestation level (Ghanim, 2009).

Ghanim *et al.* (2010) results of the study on the efficiency of insecticides in male annihilation techniques revealed that Naled mix was the most effective against *B. zonata* males especially during the first two months of hanging. It can be used in MAT of *B. zonata* and renewed every two months. Lambada, Lebaycid, Sumithion, commercial Malathion (2:3), respectively, could be used in MAT of *B. zonata* with monthly renewal.

4. Colour and food odour trapping methods

Studies on the role of colour, shape of the trap and odour as foraging stimuli in a number of *Bactrocera, Anastrepha* and *Ceratitis* groups have facilitated the development of efficient traps for monitoring and even suppressing populations of some pest species.

a) Colour traps

The discovery that certain colours attract certain species strongly, led to the use of the most powerful ones in the trapping devices. White objects are not very attractive to tephritids (Cytrynowicz *et al.,* 1982) but yellow traps baited with methyl eugenol were more attractive to *B. dorsalis* (Vargas *et al.,* 1991; Stark and Vargas, 1992). Yellow colour also attracted more olive fruit flies than any other colour (Prokopy *et al.,* 1975). Yellow traps have been tested for predicting the infestation levels based on captured females of *B. oleae* (Ballatori *et al.,* 1980; Mitchell and Saul, 1990).

Jalaluddin *et al.* (1998), Madhura (2001) and Sarada *et al.* (2001) observed that greater preference of fruit flies towards yellow and transparent traps. Similarly Rajitha and Viraktamath (2005 a, b) reported that transparent, orange and

green colour traps were attractive to *B. dorsalis*. In mango interestingly, *B. dorsalis* showed highest preference to black traps. Similar preference to black colour is also shown by *C. capitata* (Nakagawa *et al.,* 1978).

Studies were made on attraction of different species of fruit flies to different coloured traps in guava and mango orchards near Dharwad during 2005-06. Yellow and transparent traps attracted significantly high number of *B. correcta* in guava (70.45 fruit flies/trap/week) and mango (5.13 fruit flies/trap/ week), respectively. Green and orange coloured traps in guava (3.79 and 3.75 fruit flies/trap/week, respectively) black coloured traps in mango (3.88 fruit flies/trap/week) were attractive to *B. dorsalis. B. zonata* was attracted to red coloured traps (3.75 fruit flies/trap/week) in mango ecosystem. When total fruit flies irrespective of species were considered, yellow colour traps were attractive in guava (71.91 fruit flies/trap/week) while black colour traps in mango (8.68 fruit flies/ trap/week) (Ravikumar and Virakthmath, 2007).

b) Food odour traps

McPhail odour trap (McPhail, 1937) containing water solutions of ammonium salts or proteinaceous substances have been used for a long period to monitor fruit flies (Economopoulos, 1979; Bateman and Morton, 1981; Jang and Nishijima, 1990). The McPhail trap is effective for short duration, no more than 4-5 days under summer warm dry weather, breaks easily, and it is rather difficult to handle. Protein hydrolysate solutions have been found much more powerful than ammonium salt solutions (Economopoulos, 1975).

Cunningham *et al.* (1975) used 83 per cent methyl eugenol along with 10 per cent naled and 7 per cent thixein for management of *B. dorsalis.*

Cuelure traps were found to attract *B. tau,* besides *B. cucurbitae,* in peninsular Malaysia where the former was found infesting bachang, *Mangifera foetida* (Tan and Lee, 1982). Fang and Chang (1984) found 1:1 mixture of cuelure and methyl eugenol to be more attractive than methyl eugenol alone or a 20:1 mixture of cuelure and dichlorvos.

The discovery of synthetic lures *viz.,* methyl eugenol, ammonium acetate, cuelure has greatly enhanced the method for the detection, monitoring and control of fruit flies. Methyl eugenol has both olfactory as well as phagostimulatory action and is known to attract fruit flies from a distance of 800 m (Roomi *et al.,* 1993). Methyl eugenol is the most powerful tephritid male lure (Demilo *et al.,* 1994; Asquith and Kido, 1994). The effectiveness of male annihilation was found to be reduced in areas where wild males have consumed methyl eugenol from natural sources (Shelley, 1994).

A good quantum of work on male attractant methyl eugenol against *B. dorsalis* and *B. zonatus* has been done in India (Bose *et al.,* 1979; Bagle and Prasad, 1983; Shukla and Prasad, 1985; Gupta *et al.,* 1990; Rahman *et al.,* 1995; Kumar and Agarwal, 1998 and Agarwal and Kumar, 1999) as well as abroad (Ushio *et al.,* 1982; Liu, 1983; Stark and Vargas, 1992; Cheng and Lee, 1993, Qureshi and Hussain, 1993), but insufficient information is available against melon flies, *B. cucurbitae* and *B. tau* on this aspect from India or elsewhere. When the yellow trap was combined with an ammonium acetate dispenser, it catches about three times more olive flies than the yellow trap alone (Economopoulos and Stavropoulou-Delivoria, 1984).

Successful pursuit of an eradication programme using bait sprays and poisoned cuelure traps to eliminate the males was carried out in Solomon Islands against in 1985 (Eta, 1985). In Taiwan too cuelure was more effective and persistent attractant of melon fly, than methyl eugenol and protein hydrolysate (Wen, 1985). Methyl eugenol had no attractive effect on *B. cucurbitae*, but its mixture with cuelure at 3:7 parts by volume, exerted a synergistic effect on the attractant (Ramsamy *et al.,* 1987). Wong *et al*. (1991) found increased response of males with age to cuelure and corresponded to reaching sexual maturity. In India, cuelure proved more effective than tephritlure (food attractant) in bitter gourd crops in Maharashtra against B. cucurbitae (Pawar *et al.,* 1991). Liu and Lin (1992) reported that a 10 per cent cuelure-methyl eugenol mixture containing the attractants in 1: 9 ratio was most attractive for luring males of both *B. cucurbitae and B. dorsalis* and remained attractive for up to 225 days in field.

Bakri (1991) investigated the changes in responsiveness of flies in relation to progressive changes in the odour and colour of the oranges. He noted more flies attracted to mature fruit. However, fermenting fruits were the most attractive to both males and females. Orange volatiles were analysed by gas chromatography, and certain characteristic major monoterpenes such as limonene, linalool and -terpineol were tested against the flies.

Following the successful eradication of melon fly from Kume Islands in 1976, similar large scale projects were initiated in Mijako, Okinawa and Yalyama groups of islands in 1984, 1986 and 1989, respectively, and the eradication was achieved in 1987, 1990 and 1993, respectively. On these islands, prior to the release of sterile flies, suppressive control was carried out with male annihilation technique by distributing 25 cm long cotton strings soaked with cuelure and BRP (insecticide) once a month @ 40 strings/hectare from air. At the final stage of suppression, the wild male population density decreased to less than 1/ 20 of that in the same season before the control (Kakinohana *et al.,* 1997). In a survey, carried out at different sites in Nepal during 1996-97, it was found that 90 per cent of the farmers continued to use attractant traps of cuelure along with field sanitation for control, as these proved very effective (Jaiswal *et al.,* 1997).

According to Vargas *et al.* (2000) methyl eugenol and cuelure were highly attractive kairomone lures to oriental fruit fly, *B. dorsalis* and melon fly, *B. cucurbitae,* respectively. Alyokhin *et al.* (2000) observed that protein odour significantly increased the number of Oriental fruit flies captured by Ladd traps.

Papaya and guava based food baits attracted significantly more *Bactrocera* spp. at Bangalore (Madhura, 2001). Boscan

De Martinez *et al.* (2001) observed that nine per cent nulure + borax was effective in capturing *Anastrepha* spp. and *C. capitata.* Jiji *et al.* (2003) used various combinations of fruit pulp of the banana varieties like Palayamkodan, Red Banana, Robusta and Rasakadali for trapping fruit flies. Robusta, Red Banana and Palayamkodan were effective for trapping females. Combinations of fruit pulp with boiled molasses was very effective and increased the keeping quality of the food baits.

Castrejón-Gómez *et al.* (2004) captured adults of the papaya fruit fly, *Toxotrypana curvicauda* Gerstaecker, living in wild vegetation by using McPhail traps baited with pineapple juice or brown sugar. Maximum capture peaks occurred during August and November in the afternoon. Baits were most effective when aged over a 4-d period. Traps baited with brown sugar captured the highest number of adults, and both baits were more attractive to females than males. Potential use of these baits for pest management and research is discussed, considering that this is the first report of pineapple juice being attractive to the papaya fruit fly.

Thomas *et al.* (2005) evaluated two parapheromones *viz.,* cuelure and methyl eugenol for their attraction to *B. cucurbitae* in a bitter gourd field and revealed that melon flies were attracted to only cuelure traps. Singh *et al.* (2005) found that methyl eugenol male annihilation technique was the most useful. Verghese *et al.* (2005) studied the comparative attractiveness of three indigenous lures/baits with three established attractants in fruit flies and reported that methyl eugenol attracted highest number of flies (18.25 flies/day/trap) followed by cuelure (13.5 flies/day/trap) and tulsi (5.88 flies/day/trap) whereas, flies attracted to banana, jaggery and protein hydrolysate were negligible.

Among the Biolure baited traps, the orange hemispherical Maxitrap Plus, was as attractive as the McPhail-like hydrolyzed protein trap. Indeed, synthetic lures, based on ammonium acetate putrescine, combined with water or propylene glycol as a retention method can be better or similar to liquid baits in capturing Mexican fruit flies (Thomas *et al.,* 2001; Thomas, 2008). However, other authors indicate that more *A. ludens* were captured in McPhail traps baited with liquid torula yeast than with dry lures or Biolure (Heath *et al.,* 1995; Conway and Forrester, 2007). Studies on the ability of different plant extracts to attract male fruit flies carried out by Hasyim *et al.* (2007) *indicated that the major compound camphor present in Elsholtzia pubescens* (Bith) was atleast as efficient as the standard cue lure in trapping males of *B. tau* in passion fruit orchard.

Singh et al. (2007) tested sex attractant methyl eugenol, cuelure and food attractant protein hydrolysate for attraction to fruit flies and reported that five fly species *viz., B. zonata, B. affinis* (Hardy), *B. dorsalis, B. correcta* and *B. diversa* (Coquillett) were attracted to methyl eugenol traps and two species *viz., B. cucurbitae and B. nigrotibialis* (Perkins) to cuelure traps and two species namely, *B. cucurbitae* and *B. zonata* to protein hydrolysate traps. Vargas *et al.* (2009) evaluated various traps with methyl eugenol and cuelure for capturing fruit flies and observed that *B. dorsalis* was captured in methyl eugenol traps and *B. cucurbitae* in cuelure traps.

Afia (2007) and Ghanim (2009) mentioned that lures for capturing fruit flies based on food or host odors and liquid protein baits have been used to catch a wide range of different fruit fly species (females and males). Sundar *et al.* (2012) reported that the Rakshak fruit fly trap was superior to bottle fruit fly trap. Maximum fruit flies were trapped when parapheromones were replenished at one month interval (Patel and Patel, 1998; Jhala *et al.,* 2008, Shukla *et al.,* 2008 and Chua, 2009).

Deepa *et al.* (2009) also reported methyl eugenol was found to be more effective for capturing *Bactrocera* complex. Pal *et al.* (2012) recorded that it was 0.04% of total trapped flies in methyl eugenol.

Rakshak Fruit Fly Trap was found most effective to Bottle Fruit Fly Trap, trapped 35.18, 17.30 and 15.22 per cent more fruit flies during *kharif, zaid* and *rabi* season, respectively. Methyl eugenol was most effective during *kharif* and *zaid* season but cue-lure was most effective during Rabi season. Maximum fruit flies were trapped during *zaid* season. Bottle Fruit Fly Traps baited with methyl eugenol dispensed cotton wick and replenished at two month interval provide most economical and trapped 394.12 FFs on per rupee investment during *zaid* season (Sundar and Sushil Kumar, 2014).

Kiran Rana and Kanwar (2014) reported that combined treatment of cue-lure baited traps and poison bait spray was most effective in management of fruit flies with significantly less damage to fruits as compared to control rather than their separate applications.

Maharjan *et al.* (2015) recorded the highest number of fruit flies (167.5 male fruit flies / 3 traps) in cue-lure trap during the first week of September, which coincided with 85.45 per cent RH and 21.67°C and 25.04°C minimum and maximum temperature, respectively.

Ranganath *et al.* (2015) evaluated the efficacy of chemicals, botanical neem soap and bait sprays consisting of jaggery @ 15 g per litre mixed with deltamethrin @ 1 ml per litre and deployment of cuelure traps @ 15 / acre against melon fly on bitter gourd. Sanitation by collection and destruction of melon fly infested fruits was meticulously followed throughout the experimental period. Bait spray treatment coupled with sanitation and cuelure traps recorded the lowest fruit damage (14.38%) with a yield of 24.1 t per ha.

The cost-effectiveness ratio between guava juice and extract was also analyzed by Filgueiras *et al.* (2016). Results indicated that fruit flies prefer the chicken manure extract (10 %), with greater capture observed three days after trap installation, which can replace the guava juice in the agroecological management of fruit flies in guava trees in family farms, since it is low cost and efficient.

Draz *et al.* (2016) studied the efficiency of Jackson traps baited with methyl eugenol (M.E.) on male capture, that were

distributed in different fruit trees orchards, in different positions and hang levels in one of Egyptian agro-ecosystem. Jackson traps that placed in center of orchard and hanged at 2 m height were more efficient than others for male catches.

Conclusion

From the above reviews, it is clear that baits offer one of the most effective methods of control especially in the preoviposition stage when the fruit flies require plenty of water to drink and are easily attracted to any solution. Although, a lot of work has been done on the development of various baits for the control of fruit flies, however, so far, no universal, effective and exclusive technique of mass trapping has been developed to control this serious pest. An integrated approach including cultural practices such as collection and deep burying of infested and fallen fruits, tillage around the trees/in the fields in summer along with protein hydrolysate bait sprays could be employed. Bait spray application requires simple equipment and there is no problem of residues on the produce and is economical. These methods are ecofreindly as they do not have any adverse effect on pollinators and natural enemies.

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