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Efficacy of different lures in male annihilation technique of peach fruit fly, *Bactrocera zonata* (Diptera: Tephritidae)

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Abstract
With regard to significance of *Bactrocera zonata* (Saunders) as a serious pest of fruit and vegetable in Pakistan, methyl eugenol, cue-lure and protein hydrolysate were used for monitoring the population and infestation of peach fruit fly in peach orchards in Tehsil Matta Swat, Pakistan. Pheromone traps were prepared from 2cc of methyl eugenol, cue-lure, and protein hydrolysate, with mixture of sugar and 2g poison linate. The peach fruit fly (PFF), *B. zonata* adults come in descending order as follows: methyl eugenol > cue-lure > protein hydrolysate. The prepared solutions of methyl eugenol and cue-lure attracted PFF male with significantly high numbers in comparison to female while protein hydrolysate highly attracted female as compared to male. The results indicate that male peach fruit fly is highly attractive to methyl eugenol and with the help of methyl pheromone trap we can easily reduce the population of adults peach fruit fly. The 2cc of lure and 2g of poison linate can attract the peach fruit fly, *B. zonata* from a distance of 1km and killed easily up to 15 days. This "attract and kill" system combining male lure and toxicant is the most effective in suppressing fruit fly males. Thus, results show that there is potential to use methyl eugenol in *B. zonata* male annihilation techniques (MAT).

Keywords: Peach, *Bactrocera zonata*, Pheromone traps.

1. Introduction
In horticulture production throughout the world, fruit flies are one of the most important insect pests, more than 4500 species occurring worldwide [12]. It is a polyphagous species attacking some 40 species of fruit and vegetables [30]. Direct fruit damage, fruit drop, and loss of export markets through quarantine restrictions are all means by which fruit fly infestation causes economic loss. Fruit fly infestations and its resultant consequences in the shape of pesticide residues and quality deterioration of fruits are putting adverse effects on the economy of farmers and traders. Some of the fruits which could fetch foreign exchange are not being exported due to infestation of fruit flies. They are found in almost everywhere in the world with host plants [21]. Fruit flies are among the most economically important pests attacking fruits worldwide and usually attack commercial fruits [31].
The peach fruit fly, *Bactrocera zonata* (Saunders), is one of the most harmful species of Tephritidae. It causes heavy damage in Asia [4] and is a serious pest of peach (*Prunus persica)*. This fruit fly is native to tropical Asia and has been found in numerous tropical countries of Asia [30]. Female flies lay their eggs in the fruits while the maggots devour the pulp. Subsequently, secondary infections with bacterial and fungal diseases are frequent and infested fruits drop down [31].
Four hundred species belonging to the genus *Bactrocera* are widely distributed in tropical regions of Asia, South Pacific and Australia, but very few species of this genus were recorded in Africa [9]. More recently, *B. zonata* has been recorded in Egypt, where it has spread throughout the country and where control measures have been recently initiated. Annual losses due to the peach fruit fly are estimated at 190 million € in Egypt [11]. Peach, *Prunus persica* has yellow or whitish flesh, a delicate aroma, and a skin that is either velvety (peaches) or smooth (nectarines) in different cultivars [16]. Peach fruit fly is native to India where it was first recorded in Bengal [19]. In India, *B. zonata* (Saunders) is active throughout the year except the cold winter months of January and February [14]. It is present in numerous countries of tropical Asia: India, Indonesia, Laos, Sri Lanka, Vietnam, and Thailand [30]. Control of fruit flies has

been tried in various ways such as mechanical, cultural, biological and chemical. MAT (Male Annihilation Technique) with methyl eugenol and cue-lure are common in the management of fruit flies and this technique is the part of Integrated Pest Management (IPM) in early monitoring of this pest [3].

In Pakistan, the fruit fly complex may cause losses that range from 20 to 90% in different areas of the country [27]. At present, it is a significant horticultural pest in India and Pakistan [24]. About 11 species of fruit flies have been recorded that cause losses in fruit and vegetable in Pakistan and the most prominent among them are *B. zonata, B. cucurbitae, B. dorsalis, Myiopardali spardalina, Carpomiyain completa, C. suviana, acusferru gincus and Dacus diversus* [1]. They have great economic importance in Pakistan due to heavy losses to fruits at the farm level with estimated loss of 200 million US dollar annually and the small farmers suffer in particular, being the main growers of highly susceptible guava, mango, peach and cucurbits are being unable to afford existing protection measures [28]. Peach fruit fly mostly attacks to species *Prunus persica* and this species is a traditional crop of Northern area of Pakistan and occupies an area of 4543 hectares with the production of 48284 tones. Quetta, Kalat, Peshawar, Swat valley and certain parts of Kohistan hills are the main major growing areas of peach [6]. Khyber Pakhtunkhwa has temperate climate and most of the temperate fruit are successfully grown in the upper half of the province, which include plum, pear, peach and apple [20].The attack of fruit flies reduces fruit yield and quality. It infests the skin of fruit by inserting ovipositor and lay eggs beneath the skin [18]. The larvae of the fruit flies feed on the pulp of ripe fruits forming tunnels inside them causing a great damage and make fruits unfavorable for marketing and export [30].

For the management of fruit flies, we used various control measures such as chemical, biological and cultural. Insecticides used against fruit flies, organophosphates, carbamates, synthetic pyrethroids and new chemistry are being indiscriminately used by farmers as cover sprays [27]. Increasing applications of pesticides are facing resistance from environmentalists and the general public [8]. Traditional control measures using chemical insecticides experience disadvantages such as residual problems and inability of insecticides to penetrate infested fruits to kill larvae. Moreover, the public demand for insecticide-free fresh fruit is encouraging the use of environment-friendly methods of pest control [10]. Use of plant species to control insect pests has been in practice for centuries to a limited extent, only recently interest has been renewed in the pest management potential of natural products. Plants are nature's "chemical factories", providing the richest source of organic chemicals on Earth. Plant products have several uses in insect control [15]. The trapping method is applied as spot treatments by using many dispensers as carriers of methyl eugenol and toxicant (such as cotton cord, neutral gel, plant fibers blocks and felt blocks). The use of lure-and kill stations (i.e. plant fibers and felt blocks impregnated with the methyl eugenol-insecticide mixture) is often preferred [2]. Females of peach fruit flies need certain amino acids as nutrition for developing their eggs and so they are attracted by the bait [5]. The protein hydrolysate preparations uses in trap for attraction of female fruit fly (food attractants) were previously used as bait in McPhail traps [26]. The present study was aimed to investigate fruit fly, *B. zonata* infestation through different lures in peach orchard in Swat, Pakistan.

2. Materials and Methods

2.1. Trap installation site

The current studies were carried out during summer 2014 at the Agriculture Research Station Mingora Swat, Khyber Pakhtunkhwa, Pakistan to investigate the effect of different lures against fruit fly attacking Peach at Tehsil Matta of District Swat. Peach is the major fruit of Swat in Khyber Pakhtunkhwa province, therefore; different villages, Bamakhela, Chupreial, Asharry, Shakardara, Ronrrial in Tehsil Matta, District Swat, were selected for the Pheromone traps site.

2.2. Insect rearing and fruits collection

The orchard soil was collected for pupation purpose and to remove larvae of other flies by sewing, using mesh 40. In order to confirm the infestation of peach fruit fly, fruits were collected from selected villages, Shakardara, Asharry, Chupreial, Tottkay, Ronrrial and kept in different rearing cages (L: 36cm, W: 25cm, H: 35cm) having wet soil from same the orchard at the depth of 8 to 9cm. Infested fruits having maggots were placed in soil for pupation and adult fruit fly emergence.

2.3. Pheromones solutions

Pheromone traps for all orchards were prepared from the following materials:

- 2.5cc of methyl eugenol, 2g linate, 5g sugar solution, cotton, and small quantities of water bellow in trap.
- 2.5cc cure lure, 2g linate, 5g sugar solution, cotton and water.
- 2.5cc protein hydrolysate, 2g linate, 5g sugar solution, and water.

Pheromones were active for 15 days and attracted the fruit flies from a distance of 1 Km.

2.4. Pheromone traps

Pheromone trap (L: 18cm, W: 10cm, Dia. 30cm) used in this current work was cylindrical bottle with upper cover funnel shaped; having four holes on cylinder body at equal distance in opposite direction to each other. The cotton was soaked in prepared solution of lure and fixed at the front of holes with the help of wire. The methyl eugenol and cure lure were used to attract male fruit flies while protein hydrolysate was used to attract female fruit flies. Linate was used as a poison to kill the fruit flies, sugar for sweetness and water to remove the chance of life of fruit fly which came to traps. Traps of different lure in three different peach orchards of NJ4, Elberia and Meria delixa varieties were fixed and the dead fruit flies were collected after every 24 hours for 11 days and preserved in different collection boxes.

2.5. Statistical Analysis

Data was assessed for analysis of variance and difference among the lures by using computer software MSTATC and the means were separated by using the Duncan multiple range tests.

3. Results and Discussion

The purpose of current study was to determine the effect of different lures against peach fruit fly. The results of different lures are shown in Tables II-IV. The infestation of fruit fly, *B. zonata* in different peach varieties is shown in Table I.

Table 1: Collection of dropped peach varieties from different areas to check peach fruit fly infestation.

Collection date	Peach varieties	Collection place	Fruit fly emergence date
22-6-2014	Flame Crest	Totkay Matta Swat	No Emergence
2-7-2014	Carmon	Chupreial Swat	No Emergence
15-7-2014	NJC-84	Shakardara Swat	30-7-2014
23-7-2014	Elberia	Asharry Swat	No Emergence
5-8-2014	Maria delixa	Ronrryal Swat	20-8-2014
23-6-2014	Flame crest	Asharry Matta Swat	No Emergence
7-7-2014	Carmon	Drushkhela Swat	No Emergence
19-7-2014	NJC-84	Bodegram Swat	22-7-2014
29-7-2014	Elberia	Bazkhela Swat	5-8-2014
8-8-2014	Maria Delixa	Gwalerai Swat	20-8-2014
18-8-2014	Indian Blood	Gurra Swat	28-8-2014

The data (Table 1) showed peach fruit fly, *B. zonata* infestation in different peach varieties which revealed from its emergence. Peach varieties which did not show *B. zonata* emergence, revealed the infestations of other fruit fly, *Drosophila* species. The variations in the emergence of fruit flies depended on temperature and day lengths.

Table 2: Effect of different lures in different peach orchards of variety NJC-84.

Lures	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	Mean
Methyl Eugenol	8.7a	8.3a	7.0a	7.7a	7.6a	15.0a	5.0a	10.6a	9.0a	6.0a	7.0a	8.35
Cue-Lure	9.3a	5.3ab	7.6a	4.6ab	4.6ab	9.0b	5.0a	6.0ab	9.3a	5.0a	7.6a	6.66
Protein Hydrolysate	1.3b	1.33b	2.00b	1.3b	1.3b	2.6c	1.6b	1.0b	2.0b	1.6b	1.6b	1.60
Mean	6.44	4.88	5.55	4.55	6.33	8.88	3.88	5.88	6.77	4.22	5.44	5.53

($LSD_{0.05}$ for methyl eugenol, cue-lure and protein hydrolysate are 8.3, 6.6 and 1.6 respectively). Means followed by different letter(s) are significantly different from each other (LSDs test P< 0.05)

The efficacy data (Table 2) of different lures in three different orchards of peach variety NJC-84 revealed that methyl eugenol and cure-lure were significantly high effective on day 1st, 3rd, 7th, 9th, 10th and 11th followed by protein hydrolysate. However, on day 2nd protein hydrolysate followed methyl eugenol with no significant difference from cure-lure. Similarly, protein hydrolysate revealed the same pattern on day 4th, 5th, and 8th. Significantly high effect was shown by methyl eugenol on day 6th followed by cure-lure and protein hydrolysate.

Table 3: Effect of different lures in different peach orchards of variety Elberia.

Lures	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	Mean
Methyl Eugenol	5.67a	10.33a	12.00a	7.00a	11.33a	14.67a	10.00a	9.67a	10.00a	9.67a	10.67a	10.09
Cue-Lure	5.67a	3.67b	8.33a	7.00a	7.67a	5.00b	7.67a	7.00a	7.00a	7.00a	7.00a	6.63
Protein Hydrolysate	1.67a	1.33c	1.67b	1.67a	1.67b	1.67c	2.33b	1.67b	2.00b	1.33b	2.33b	1.75
Mean	4.33	5.11	7.33	5.22	6.88	7.11	6.66	6.11	6.11	6.00	6.66	6.15

($LSD_{0.05}$ for methyl eugenol, cue-lure and protein hydrolysate are 10.09, 6.63 and 1.75 respectively). Means followed by different letter(s) are significantly different from each other (LSDs test P< 0.05)

The efficacy data (Table 3) of different lures in three different orchards of peach variety Elberia shown that methyl eugenol was significantly high effective on day 2nd and 6th followed by cure-lure and protein hydrolysate. However, on day 1st and 4th methyl eugenol showed no significant difference from cure-lure and protein hydrolysate. Cure-lure was significantly high effective from protein hydrolysate on day 3rd, 5th, 7th, 8th, 9th, 10th and 11th with no significant difference from methyl eugenol.

Table 4: Effect of different lures in different peach orchards of variety Maria Delixa.

Lures	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	Mean
Methyl Eugenol	12.67a	8.00a	10.67a	10.67a	8.67a	13.67a	10.00a	12.33a	13.33a	11.33a	9.67a	11.78
Cue-Lure	4.33b	3.67b	5.67b	5.33b	5.00b	6.67b	4.67b	4.67b	9.33a	5.00b	6.67a	5.54
Protein Hydrolysate	1.33b	2.00b	2.67b	2.67b	1.33c	2.33b	1.67b	2.00b	2.00b	2.67b	1.3b	1.99
Mean	6.111	4.555	6.333	6.222	5.000	7.555	5.444	6.333	8.222	6.333	5.888	6.43

($LSD_{0.05}$ for methyl eugenol, cue-lure and protein hydrolysate are 11.0, 5.54 and 2.0 respectively). Means followed by different letter(s) are significantly different from each other (LSDs test P< 0.05)

The efficacy data (Table 4) of different lures in three different orchards of peach variety Maria delixa revealed that methyl eugenol showed highly significant effect on day 1st to 8th as well on day 10th followed by cure-lure and protein hydrolysate. However, on day 9th methyl eugenol showed no significant difference from cure-lure. Conversely, cure-lure showed highly significant difference from protein hydrolysate on day 9th.

Our results regarding methyl eugenol are in conformity with the report of Chambers *et al*. (1974) [7] and Ghanim *et al.* (2010) [13] who reported that methyl eugenol was highly attractive to *B. zonata* chamber and Sanderson reported that

Naled-methyl eugenol mixture exhibited the highest efficiency against *B. zonata* males in comparison with the mixtures. Similarly, our findings regarding methyl eugenol are slightly parallel to the reports of Nabil (2013) [23] who used methyl eugenol as a mixture and revealed that *B. zonata* males were more attracted to methyl eugenol-spinosad in comparison to methyl eugenol-fentrithion and methyl eugenol-thiamethoxam+abamactin mixtures. The observations made by Saeidi and Nur (2011) [17] and Steiner *et al*. (1965) [25] are likewise in conformity with our findings who revealed that methyl eugenol was highly effective against male fruit fly by registering more attraction. However, the observations of Moustafa (2009) [22] deviated from our findings of more PFF male attraction, who reported more PFF females' attraction by using Glan, pro-lure 2%, Agrisene, Bioprox, pro-lure 5%, Amadene, Buminal, Norlan and Agrinal. In Hawaii, bucket traps with cotton dispensers containing methyl eugenol and either Naled, Malathion, or DDVP proved effective against *B. dorsalis* or *B. cucurbitae* for 20 weeks without replacement of the lure or toxicant. The efficiency of blocks reduced by 50% after 8 weeks (Vargas *et al*., 2003) [29].

4. Conclusion

Among the selected lures, methyl eugenol was most effective against *B. zonata* males as compared to cure-lure and protein hydrolysate. On the bases of observed results, it is recommended that methyl eugenol could be used in Male Annihilation Technique (MAT) of *B. zonata.*

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