



Research Article

Field Evaluation of Different Pest Management Strategies against Citrus Fruit Fly, *Bactrocera dorsalis* Hendel

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Authors' Contributions

ABMR and MZM planed the research idea and protocol. MI executed the field trials and prepared results. MZM and ZQ performed statistical analyses. MI and MZM prepared the first draft. ZQ proofread the manuscript for English language. ABMR supervised the research and provided technical support in experimentation.

Keywords

Bactrocera dorsalis, Tephritidae, Integrated pest management, Methyl eugenol trap, Protein hydrolyzate bait, Cultural control



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Abstract | Fruit flies (Tephritidae: Diptera) are among the most destructive and economic pests of horticultural crops. They infest and destroy a wide range of fruits. *Bactrocera dorsalis* Hendel is an emerging threat to the export of Pakistani citrus fruits to overseas markets. Integrated pest management (IPM) is an appropriate and sustainable strategy for controlling fruit flies as it is based on integrated application of all available pest control methods with minimum implication of hazardous synthetic insecticides. In this study, five treatments including field sanitation (T_1), pheromone-based attract and kill strategy (T_2), protein-based bait method (T_3), combination of all three methods (T_4) and control (T_5) were evaluated against *B. dorsalis* infestation in citrus during 2015 and 2016. Data of percent infested fallen fruits, percent pupae recovered from these fallen fruits, percent adult deformity, percent sex ratio and cost-benefit ratio were recorded. Results showed that when all of the components were used together (T_4), fruit damage was significantly reduced remained 0.32 to 0.49% in both years. In addition, T_5 (control) plots where no IPM treatments were applied showed highest number of infected fruits (3.06 to 4.59%) in both years. Moreover cost-benefit ratio was lowest for the combined treatment (T_4) during both years i.e., 2.7:1 for 2015 and 3.08:1 for 2016 as compared to other treatments. Overall results of this field trial demonstrate the significance of integrated pest management strategies in reducing the fruit flies infestation and enhancing citrus fruit yield.

Novelty Statement | This field study demonstrates the practical significance of integrating different pest management techniques, i.e. field sanitation practices, installation of methyl eugenol pheromone based male fly trapping and application of protein hydrolyzate based female fly trapping baits, for the management of fruit fly infestation in citrus orchards. Combination of these IPM strategies significantly reduced fruit infestation and enhanced fruit yield.

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Introduction

Fruit flies are destructive pests of a wide range of horticultural crops. They attack and destroy many fruits such as guava, citrus, mango and vegetables such as

tomatoes, pepper and cucurbits. They have enormous host range, strong reproductive potential and climate adaptation (Sarwar *et al.*, 2014; Theron *et al.*, 2017). *Bactrocera dorsalis* (Hendel), also known as oriental fruit fly, is one of the most destructive pests of fruits and vegetables in South East Asia and in the Pacific region due to its polyphagous nature (Orankanok *et al.*, 2007; Sarwar *et al.*, 2014; Theron *et al.*, 2017).

B. dorsalis is a severe horticultural pest in Pakistan. Farmers particularly guava, mango and citrus growers suffer considerable quantitative and qualitative losses due to its infestation (Ahmad and Begum, 2017; Ahmad *et al.*, 2019; Khuhro, 2021). Farmers exclusively rely on the recurrent applications of persistent synthetic insecticides to control fruit fly infestations in their orchards (Khan and Akram, 2018) resulting in environmental contamination and health hazards due to pesticidal residues (Sayed *et al.*, 2014). Moreover, many field populations of *B. dorsalis* in Pakistan have developed resistance against commonly used insecticides such as spinosad and trichlorfon (Khan and Akram, 2018).

Integrated pest management (IPM) refers to a strategic approach encompassing all feasible and available measures to lower the population of different insect pests in order to prevent the hazardous use of toxic insecticides (Kogan, 1998). It is imperative to integrate different fruit fly management strategies in order to mitigate indigenous farmers' reliance on synthetic pesticides. Adult fruit flies are usually targeted in most of the pest management programs as it is complicated to control egg and larval or pupal stages of fruits because these are found either inside the fruit or under soil surface (Dias *et al.*, 2018; Riaz *et al.*, 2022). This field study was aimed to evaluate the effectiveness of three commonly used IPM strategies, *i.e.* cultural control (field sanitation), pheromone-based male fly trapping and protein-based female fly baiting, either alone or in combination against fruit fly infestation and yield of citrus fruits in district Sargodha.

Materials and Methods

The experiment was conducted during the years of 2015 and 2016 at farmer's citrus fields (cv. Kinnow mandarin *Citrus reticulata* var. Blanco) located in district Sargodha. Treatments as described below included control, cultural control (T_1), pheromone-based male fly attract strategy (T_2) and female fly attract-and-kill strategy (T_3) and their integration (T_4). Experimental design was randomized complete block (RCBD) with five treatments replicated thrice in three randomly selected citrus orchards. Each orchard had a one hectare size and was divided into four blocks. All other standard agronomic practices were applied at proper time. Thirty fruits were randomly selected from each treatment plot. For each fruit picking,

safe and damaged fruits were separately collected, recorded and data were collected based on the total percentage of fruit infestation within a particular treatment. Criteria to affirm infested fruits were based on the larval-exit hole or presence of maggots on fruits (Figure 1A and B).

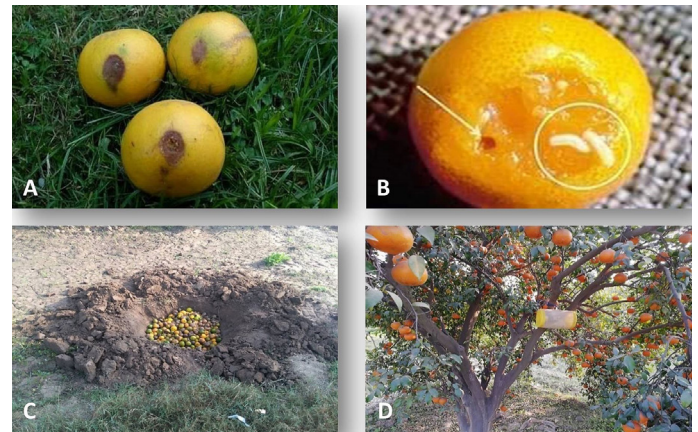


Figure 1: Fruits having maggots inside the fruit pulp (A) and spoiled citrus fruits (B) counted as fruit fly damaged fruits, burying of fruit fly infested fruits in soil (C) and methyl eugenol pheromone-based male fly traps (D).

Cultural control method (T_1)

Three random orchards of almost uniform age (6 years) were selected based on fruit fly infestation for this treatment, and no insecticides were applied during the experiment. Sanitation measures including ploughing, field hygiene and weeding were practiced. Collection and destruction of under-canopy fallen fruits were done from these orchards at fifteen-day intervals. At regular intervals, these fruits were gathered and buried in the ground at a depth of 10 to 12 inches and the soil was tightly compacted to prevent the emergence of any larvae, pupae or adults from them (Figure 1C).

Pheromone-based male fly trapping (T_2)

It was involved installation of plastic traps (Figure 1D) having a male lure and an insecticide to attract-and-kill the male fruit fly population. After every 14 days, 0.5 ml of methyl eugenol (4-allyl-1, 2dimethoxy benzene-carboxylate) plus spinosad insecticide (3:1) was added to each trap. Traps were hanged on trees at 1.5 to 2.0 meter above the ground. Data was collected after 15 days of interval. Ten plants were selected from each orchard for data collection. Data of fruits infestation were recorded as described above.

Protein-based female fly baiting (T_3)

Ten plants were selected randomly from each orchard. Bait solution containing one liter of protein hydrolyzate plus three milliliter of malathion 50 EC (95:05) mixed in 967ml water was applied on these selected plants twice with a 10 days interval, starting at the fruit setting stage using battery-operated knapsack sprayer (Model: AP-16B). Protein bait was applied inside about 50 to 100 ml

on the edges of the canopy. Data of fruit infestation was recorded at 15 days intervals.

Combination of three treatments (T₄)

In combined treatment, all three above mentioned strategies including cultural control, male traps and female baits were applied collectively in the single orchard. The experiment was replicated three times in three different orchards/blocks. Ten plants were chosen at random for bait application across the orchards. The entire orchard was practiced under cultural control. Four traps per acre were set up for trapping male fruit flies.

Control treatment (T₅)

The control treatment was selected 3 km away from other treatments. No treatments were applied in T₅. The infestation level was recorded as described in previous treatment. During the fruiting season, data were collected for two consecutive years 2015 and 2016 and fruit infestation and yield data were calculated by taking their average and percentages.

Cost-benefit analysis

The costs involved with each treatment were focused on the appropriate inputs to manage each treatment. Costs of transport and equipment rates were collected from the local markets. The gross variable costs had calculated as the sum of both the total quantity of used inputs/labour and market prices. Fruit selling prices were based on the price that smallholders could get by selling their products to the local market. Price used in the study to calculated cost-benefit ratio was based on the average of interviews of ten members from the local market (Sargodha). This is a quantitative approach used to measure the costs and benefits of alternative investments over a particular period.

Statistical analysis

Using software Statistica® 8.0 (Statsoft Inc., USA), the effects of treatments on fruit infestations and fruit yield/loss were evaluated by one way analysis of variance (ANOVA) and the treatment means were compared using the least significant difference (LSD) post-hoc test.

Results and Discussion

All above mentioned treatments were employed in

Table 1: Cost-benefit ratio of citrus orchards/plots treated with different fruit fly management strategies.

| Treatments | 2015 | | | 2016 | |
|--|------------------|---------------|-------|---------------|--------|
| | Total cost (Rs.) | Benefit (Rs.) | CBR | Benefit (Rs.) | CBR |
| Cultural control (T ₁) | 55,000 | 1,90,000 | 3.5:1 | 2,20,000 | 4.0:1 |
| Methyl eugenol based trap (T ₂) | 66,000 | 2,11,000 | 3.2:1 | 2,35,000 | 3.6:1 |
| Protein hydrolysate based bait (T ₃) | 60,000 | 2,05,000 | 3.4:1 | 2,27,000 | 3.7:1 |
| Combined application (T ₄) | 81,000 | 2,22,000 | 2.7:1 | 2,50,000 | 3.08:1 |
| Control (T ₅) | 50000 | 187000 | 3.7:1 | 1,97,000 | 3.9:1 |

order to assess the damage caused by fruit flies particularly by *B. dorsalis* in citrus orchards. Fruit infestation was observed in the treated and control plots and was found significantly affected by different treatments (p= 0.018, LSD= 0.096). During 2015, treatment with combined management strategies (T₄) was the most effective as only 0.49 % fruit damage/infestation was recorded, followed by protein hydrolyzate based treatment (T₃) and pheromone based male traps treatment (T₂) causing 1.53 and 1.58% fruit infestations, respectively. The infestation was 3.81% in the cultural treatment practiced with field sanitation etc. (T₁). Maximum fruit infestation (i.e. 4.59%) was recorded in control (T₅) (Figure 2).

In 2016, the application of these treatments resulted in a significant reduction in fruit infestation level in the treated plots. Similar trend of fruit infestation was observed this year as well. The least infestation was observed in combined treatment (T₄). The infestation level was reduced from 3.81 to 1.49 % in cultural treatment (T₁), from 1.58 to 0.65% in pheromone traps treatment (T₂), from 1.53 to 0.94% in protein bait treatment (T₃) and from 0.49 to 0.32% in combined treatment (T₄) plots. Maximum fruit infestation (i.e. 3.06%) was recorded in control treatment plots. The combined treatment (T₄) appeared significantly different and successful than all other treatments, followed by pheromone traps treatment (T₂), protein bait treatment (T₃) and cultural treatment (T₁), while maximum infestation was recorded for control treatment (T₅) plots (Figure 2).

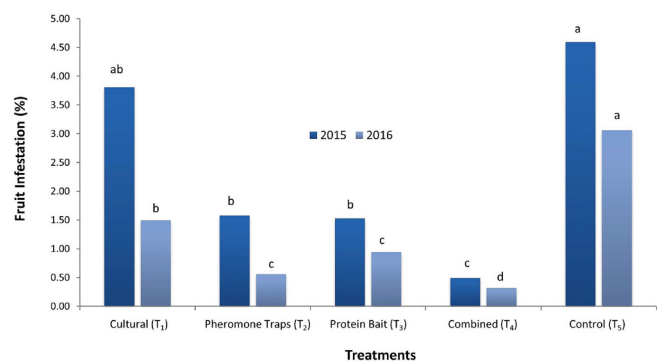


Figure 2: Percent fruit infestation (mean ± SD) incurred by *Bactrocera dorsalis* activity in citrus orchards treated with different IPM strategies in years 2015 and 2016.

In both seasons, total variable costs were highest in the combined (T_4) treatment followed by bait (T_3) treatment and the lowest costs were calculated for the control (T_5) treatment. Marketable fruit yield in combined (T_4) treatment was significantly different from other both IPM treatments, but yields for all these treatments were significantly higher than the control treatment. Cost-benefit ratio (CBR) was lowest in combined (T_4) treatment during both years *i.e.* 2.7:1 for 2015 and 3.08:1 for 2016 as compared to other treatments. As compared to control treatment, an average increase of PKR 31,000/- in the income and about 15.5% in 2015, and 21.2% in 2016 in yield was recorded for the plots treated with all three IPM strategies (T_4) (Table 1).

In this research, we assessed the efficacy of different pest management techniques for the control of fruit fly infestation for two citrus fruiting seasons. Treatments included cultural control, installation of pheromone traps, application of protein hydrolyzate bait solution and a combination of these three methods. The application of pheromone traps and bait application resulted in a significant drop in *B. dorsalis* population and fruit infestation in the first season (during 2015), while in the subsequent season (during 2016) a sudden drop in infestation level, as well as fruit fly population density was observed. Verghese *et al.* (2004) reported a similar trend in the suppression of *B. dorsalis* by these IPM techniques. A number of fruit fly population and infestation suppression strategies including the application of cultural /field sanitation practices, pheromone and protein based attract and kill strategies have been found effective against fruit flies (Basit *et al.*, 2018; Aluja, 2020; Riaz *et al.*, 2022).

Field sanitation in fruit orchards is an important part of IPM programs whereby the infested fruits are collected and buried under soil to stop the fruit fly multiplication. It is critical to remove the contaminated fruits at regular time intervals in order to limit the fruit fly population in the area. A similar method was used by Verghese *et al.* (2004). As tephritid larvae pupate under the fallen fruit, leaf litter or soil. Sanitation drastically reduces the population of fruit flies in the fields (Stringer *et al.*, 2017). This method not only reduces the use of toxic substances but also disrupts the life cycle of the fruit fly, reducing its invasion in the coming years (Muriithi *et al.*, 2021). However, this method is insufficient to entirely eliminate the fruit fly population (Theron *et al.*, 2017).

Furthermore, the application of methyl eugenol pheromone based male fly traps and protein hydrolyzate based female fly bait application resulted in a significant reduction of *B. dorsalis* population and fruit infestation either alone or in combination. These results are supported by Bharadiya *et al.* (2017) who found that pheromone and bait combination exhibited high population reduction in a

field. These results are consistent with some other previous studies (Katsoyannos *et al.*, 1999; Bharathi *et al.*, 2007; El-Gendy, 2012; Ballo *et al.*, 2020).

Parapheromones such as methyl eugenol and cue-lure and protein hydrolyzate based baits have been successfully demonstrated as effective tools to detect, monitor and mass collect fruit flies population all over the world. These Parapheromones and baits have the ability to attract fruit flies from a great distance (Fabre *et al.*, 2003; Tan *et al.*, 2014; Kibira *et al.*, 2015; Ahmad and Begum, 2017; Wazir *et al.*, 2019; Pereira and Carvalho, 2020; Nai *et al.*, 2022).

Conclusions and Recommendations

In brief, findings of this field study showed the effectiveness cultural practices, pheromone-based male fly traps and protein based female fly bait application either alone or in combination against fruit fly infestation and significantly decreased the yield and cost-benefit ratio as compared to control treatment. Based on these findings, it is concluded that combining different IPM methods such as field sanitation and attract and kill traps and baits could be effective to control fruit fly infestations in citrus orchards.

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Conflict of interest

The authors have declared no conflict of interest.

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