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SJ Saji
Department of Entomology, RCSM College of Agriculture Kolhapur, MPKV, Rahuri, Maharashtra, India

UB Hole
Department of Entomology, RCSM College of Agriculture Kolhapur, MPKV, Rahuri, Maharashtra, India

AS Bagde
Department of Entomology, RCSM College of Agriculture Kolhapur, MPKV, Rahuri, Maharashtra, India

US Shinde
Department of Horticulture, RCSM College of Agriculture Kolhapur, MPKV, Rahuri, Maharashtra, India

Corresponding Author:
SJ Saji
Department of Entomology, RCSM College of Agriculture Kolhapur, MPKV, Rahuri, Maharashtra, India

Efficacy of insecticides and biopesticides against mango fruit fly, *Bactrocera dorsalis* Hendel (Diptera: Tephritidae)

SJ Saji, UB Hole, AS Bagde and US Shinde

Abstract
The investigation entitled "Efficacy of Insecticides and Biopesticides Against Mango Fruit Fly, *Bactrocera dorsalis* Hendel (Diptera: Tephritidae)" was conducted at the District Agricultural Farm, Karimbam during 2020-21. The main objective of the work was standardizing the use of chemicals in field spray for its management.
During the period of investigation, the mean maximum and minimum temperatures recorded was 36 ºC and 28 ºC respectively, with a relative humidity of 70.8 percent. Bio efficacy of insecticides were tested in field conditions. Observations on percent fruit infestation were recorded at 10 days after spray in each treatment. Total 3 sprays were done at 10 days interval after noticing the ovipositional marks on mango fruits during fruiting stage of the crop. Among the insecticides evaluated lowest reduction of percent fruit infestation was observed in treatments lambda cyhalothrin 5 EC @ 25 g a.i/ha (23.87%) and azadirachtin 0.03% @ 3 ml/l (25.18%) which are at par with each other. The next effective treatment was imidacloprid 17.8 SL @ 30 g.a.i /ha which recorded an infestation of 34.78%. The highest percent fruit infestation was recorded in the treatment *Beauveria bassiana* WP 2% @ 20 g/L (58.35%). Lambda cyhalothrin 5 EC was the superior treatment in comparison with the mean yield per plant, net monetary return and benefit cost ratio, followed by azadirachtin 0.03% and imidacloprid 17.8 SL.

Keywords: Mango, biopesticides, insecticides, fruit fly, infestation

Introduction

The *Bactrocera dorsalis* (Hendel), Oriental fruit fly, is one of the five most aggressive and destructive fruit flies in the world. Due of its great polyphagy, it has been observed on more than 250 different host plant species (Aketarawong *et al*., 2014) [1]. The Oriental fruit fly, *Bactrocera dorsalis* (Hendel) (Diptera: Tephritidae), is the most harmful and destructive of these pests. It can be viewed as a significant obstacle to mango exports because it has an impact on both the quantity and quality of mango fruits. It is a devastating pest of orchard systems and causes significant economic harm to fruit plants. They disrupt the global production systems for both fruits and vegetables and inflict enormous economic losses.
With their ovipositors, the female fruit flies pierce the mature mango's skin and lay their eggs in the flesh of the fruit. After hatching, the maggots bore through the mango fruit's flesh, ruining it and rendering it unfit for human consumption. Fruits that are infected start to rot as a result of subsequent fungus and bacterial infestation. When a fruit is infected, several white maggots can be observed crawling in the pulp, even though the fruit may not always exhibit obvious signs of an attack. Due to fruit fly infestations, a significant amount of mango fruits is destroyed each year. Depending on the mango type and the availability of sensitive fruits at different times of the season, the yield loss caused by fruit flies typically ranges from 40 to 70% (Hossain *et al*., 2020) [3].
To control this pest and reduce possible losses, several management techniques are used. However, because three phases of this insect's life cycle are hidden and only the adult stage is visible, the control methods used to manage this pest are limited (Maharjan *et al*., 2015) [6]. There is currently no viable biological agent that can control the population of fruit flies. Therefore, it is always crucial to incorporate the most effective management techniques into the pest control strategy with the ultimate goal of boosting output, minimizing losses and protecting the environment. As a result, ecologically sound novel pesticide compounds with diverse modes of action are required for the management of fruit flies.

Materials and Methods

Field evaluation was conducted to select the most promising treatments for the management of mango fruit fly. The experiment was conducted in simple randomized block design. There were eleven treatments including control and each replicated three times.

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Treatment details		:	Insecticides	
Tr. No.	Name of insecticide		Dosage (g a.i/ha)	Formulation dose/L
T_1	Imidacloprid 17.8 SL	:	30	0.3 ml
T_2	Lambda cyhalothrin 5 EC	:	25	1 ml
T_3	Spinosad 45 SC	:	45	0.4 ml
T_4	Dimethoate 30 EC	:	450	3 ml
T_5	Malathion 50 EC	:	625	2.5 ml
T_6	Buprofezin 25 SC	:	250	2 ml
T_7	Thiamethoxam 25WG	:	50	0.4 g
T_8	Deltamethrin 2.8 EC	:	7	0.5 ml
T_9	Azadirachtin 0.03%	:	3 ml/L	3 ml/L
T_{10}	*Beauveria bassiana* WP 2%	:	20 g/L	20 g/L
T_{11}	Untreated control		--	--

Insecticides Application

Field evaluation for determining the efficacy of insecticides were conducted. Three sprays of insecticides were applied separately on the crop at an interval of 10 days besides the control. Sprays were mainly directed on to the fruits and not the whole canopy, which reduced the spray volume to 6 L. First spray was given at the maturity stage, on 18th June, 2021 when ovipositional marks were started to notice on mango fruits followed by second and third spray after 10 days interval. With the help of a motorized rocker sprayer all insecticides were applied. Insecticidal solutions were prepared by taking recommended quantity of insecticides and mixed with water to obtain desired concentration of spray solution. Spraying was done during morning hours.

Method of recording observations

Six trees in each treatment (2 trees/replication) were selected for analysis of experiment. The marketed size fruits were harvested separately in each treatment at 10 days after spraying. The ripe fruits after plucking were observed for presence of oviposition marks on their external surface and fruits having oviposition marks were considered as damaged fruits. The pre-count observations were recorded one day before application of insecticides. Pre-count infestation before first spray was calculated by randomly selecting 30 fruits per treatment and observed for presence of oviposition marks. The observations at 10 days after first and second spray were considered as pre-count observation of second and third spray. The percent fruit infestation was computed on the basis of number of infested fruits out of total number of fruits harvested. The data thus obtained were converted into arcsine transformation and then statistically analyzed.

Fruit infestation (%) = (Number of infested fruits / Total number of fruits harvested) ×100

To find effectiveness of treatments in monetary terms, the benefit cost ratio was calculated by recording yield in different treatments along with control. Cost of insecticides, fertilizers, irrigation, intercultural operations, spraying and harvesting of fruits were calculated to find total cost of cultivation. The increase in yield over control in different treatments were calculated as follows (Diksha *et al.*, 2019) [2]

Increase in yield over control (kg) = Yield in treatment (kg) – Yield in control (kg)

Result and Discussion

1. Percent Fruit Infestation after First Spray

Before spray, the percent fruit infestation ranged from 50.00 to 63.33%. The trees were treated with insecticides and ripe fruits were harvested separately in each treatment for taking observation on presence of oviposition marks made by adult fruit flies 10 days after the spray. All treatments were shown to be more effective than the control 10 DAS (days after spray). The lowest percent fruit infestation was recorded in the treatment lambda cyhalothrin 5 EC @ 25 g a.i/ha (35.89%) followed by azadirachtin 0.03% @ 3 ml/l (37.50%) and imidacloprid 17.8 SL @ 30 g.a.i /ha (39.43%) which are at par with each other. The next best effective treatment was spinosad 45 SC @ 45 g a.i/ha which recorded a percent fruit infestation of 43.24% followed by dimethoate 30 EC @ 450 g a.i/ha (47.88%). Treatments deltamethrin 2.8 EC @ 7 g.a.i/ha and malathion 50 EC @ 625 g a.i/ha showed a similar percent infestation of 54.54 and 54.76% respectively. Highest percent fruit infestation was recorded in treatment *Beauveria bassiana* WP 2% @ 20 g/L (60.97%) followed by buprofezin 25 SC @ 250 g.a.i/ha (59.15%) and thiamethoxam 25 WG @ 50 g. a.i/ha (60.25%) respectively. The percent fruit infestation in control recorded 66.66% ten days after first spray.

2. Percent Fruit Infestation after Second Spray

Percent fruit infestation 10 days after second spray showed that the best effective treatment was lambda cyhalothrin 5 EC @ 25 g a.i/ha which recorded a lowest reduction in fruit infestation of 23.21% followed by azadirachtin 0.03% @ 3 ml/l (25.00%). Both of these treatments were at par with each other. Imidacloprid 17.8 SL @ 30 g.a.i /ha and spinosad 45 SC @ 45 g a.i/ha are the next effective treatments which recorded an infestation of 36.66 and 38.56%. However, treatments such as *Beauveria bassiana* WP 2% @ 20 g/L, buprofezin 25 SC @ 250 g.a.i/ha and thiamethoxam 25 WG @ 50 g. a.i/ha recorded highest percent fruit infestation of 57.57, 56.89 and 55.55% respectively.

3. Percent Fruit Infestation after Third Spray

Lambda cyhalothrin 5 EC @ 25 g a.i/ha (12.5%) and azadirachtin 0.03% @ 3 ml/l (13.04%) are the best effective treatments which recorded the lowest fruit infestation percent 10 days after third spray. All treatments showed a significant reduction in fruit infestation when compared to control, which recorded 76.47% after third spray. The next effective treatments were imidacloprid 17.8 SL @ 30 g.a.i /ha (28.26%) followed by spinosad 45 SC @ 45 g a.i/ha (32.00%) and dimethoate 30 EC @ 450 g a.i/ha (37.50%) respectively. The recommended insecticide malathion 50 EC @ 625 g a.i/ha showed a percent fruit infestation of 42.85%. Treatments buprofezin 25 SC @ 250 g.a.i/ha (50%) and thiamethoxam 25 WG @ 50 g. a.i/ha (52.17) were at par with each other.

4. Cumulative Efficacy of Insecticides against Fruit Flies Infesting Mango

The mean percent fruit infestation after three sprays revealed that lambda cyhalothrin 5 EC @ 25 g a.i/ha (23.87%) and azadirachtin 0.03% @ 3 ml/l (25.18%) are the best effective treatments to control mango fruit fly infestation. The lowest infestation of these treatments may be due to female fruit flies' ovipositional behaviour, feeding deterrency and repellence towards the insecticide. The next effective treatment was imidacloprid 17.8 SL @ 30 g.a.i /ha which recorded an infestation of 34.78% followed by spinosad 45 SC @ 45 g a.i/ha (37.93%) and dimethoate 30 EC @ 450 g a.i/ha (43.40%) respectively. Treatments such as malathion 50 EC @ 625 g a.i/ha (49.20%) and deltamethrin 2.8 EC @ 7 g.a.i/ha (50.12%) were at par with each other. Buprofezin 25 SC @ 250 g.a.i/ha and thiamethoxam 25 WG @ 50 g. a.i/ha showed a similar fruit infestation of 55.35 and 55.99% respectively. Highest percent fruit infestation was recorded in the treatment *Beauveria bassiana* WP 2% @ 20 g/L (58.35%) (Table 7). The order of percent fruit infestation were as followed: lambda cyhalothrin 5 EC < azadirachtin 0.03% < imidacloprid 17.8 SL < spinosad 45 SC < dimethoate 30 EC < malathion 50 EC < deltamethrin 2.8 EC < buprofezin 25 SC < thiamethoxam 25WG < *Beauveria bassiana* WP 2%.

5. Benefit Cost Ratio of Insecticides application against Fruit Fly *Bactrocera dorsalis* in Mango

As revealed from the data presented in table, the mean yield per plant was highest for lambda cyhalothrin 5 EC (13.07 kg/plant) followed by azadirachtin 0.03% (12.05 kg/plant) and Imidacloprid 17.8 SL (10.7 kg/plant). The recommended insecticide malathion registered 7.26 kg/plant. The treatments spinosad 45 SC, dimethoate 30 EC, buprofezin 25 SC, deltamethrin 2.8 EC, thiamethoxam 25WG and *Beauveria bassiana* WP 2% records a mean yield of 8.09, 7.75, 6.77, 7.46, 5.63 and 5.83 kg/plant respectively. The additional income over control was highest for lambda cyhalothrin 5 EC (Rs. 804/plant) followed by azadirachtin 0.03% (Rs. 702/plant) and Imidacloprid 17.8 SL (Rs. 567/plant) where it was lowest in *Beauveria bassiana* WP 2% (Rs. 80/plant). BC ratio was calculated out to find the monetary returns, which revealed that the best treatment was lambda cyhalothrin 5 EC (3.51) followed by azadirachtin 0.03% (3.03) and imidacloprid 17.8 SL (2.91). The incremental cost benefit ratio showed that lambda cyhalothrin 5 EC was the superior treatment among the insecticides tested.

These results were similar with the studies of Diksha *et al*., (2019) [2] in which they evaluated the bioefficacy of some insecticides and biopesticides against fruit fly, *Bactrocera* spp. infesting bottle gourd. Results of field trials shows among insecticides lambda cyhalothrin was superior with least fruit infestation (14.62%) and maximum avoidable loss value (47.93%) proved effective in managing fruit flies. Among biopesticides, spinosad was the better treatment with 17.38% infestation and azadirachtin though inferior over the synthetic pyrethroid, were also found effective in reducing fruit infestation.

Studies conducted by Verghese *et al*., (2020) [10] to refine the prevailing management strategies of fruit fly, *Bactrocera dorsalis* in mango revealed that application of a neem-based pesticide on trees during fruiting stage along with methyl eugenol traps created a push-pull environment to female and male fruit flies, respectively, thereby significantly bringing down the fruit fly infestation. Here, the olfactory deterrence disorients and wards off the gravid female fruit flies thus preventing oviposition and infestation.

Nadeem *et al*., (2012) [8] evaluated the resistance ratio of six insecticides *viz*., trichlorofon, bifenthrin, malathion, methomyl, lambda–cyhalothrin and spinosad against fifteen field population of *Bactrocera zonata* and record malathion showed the lowest activity (LC50, 4.96 μ g L–1) followed by in methomyl (3.88 μ g L–1), spinosad (3.69 μ g L–1), bifenthrin (2.58 μ g L–1), lambda–cyhalothrin (2.42 μ g L–1) and trichlorfon (2.38 μ g L–1) against susceptible strain of *B. zonata*.

Study conducted by Khursheed and Desh (2012) [5] reported that the superiority of lambda–cyhalothrin in term of minimum fruit infestation as well as low number of maggots per infested fruit. The low water solubility and high binding affinity of lambda–cyhalothrin with plant surface might have contributed in its bioefficacy against fruit flies. However, mean number of maggot population per infested fruit was less in azardirachtin treatment than the lambda–cyhalothrin on cucumber and bitter gourd crops. Verghese *et al*., (2012) [12] found that formulation of neem can easily supress the population of *Bactrocera cucurbitae* and *Bactrocera dorsalis* on bitter gourd. They observed that, neem blocks the ovarian development of female flies and it can be used as an alternative to insecticides for the safe control of *Bactrocera* species.

In a similar study, Khatun *et al*., (2016) [4] reported that lambda-cyhalothrin (0.005%) is effective in checking *B. cucurbitae* infestation in bitter gourd with 17.23 percent infestation in comparison to 38.40 percent in control, These results are in line with the findings of the present study. Thakur and Gupta (2013) [9] recorded the highest oviposition deterrence of *Azadiracta indica*, 90.1 and 88.7 percent against *B. tau* and *B. cucurbitae* in the study of plant extracts as oviposition deterrents against fruit flies in vegetables. Maulid *et al.,* (2015) [7] in their study on integrated pest management against *Bactocera dorsalis* in mango recommended broadcast spray of karate (Lambda cyhalothrin) for commercial farmers, mostly targeting regional markets.

Table 1: Cumulative efficacy of insecticides against fruit flies infesting mango

Tr. No.	Name of Treatments	Dose (ml or g/L)	Mean percent fruit infested			Cumulative percent infestation
			Spray 1	Spray 2	Spray 3	
T_1	Imidacloprid 17.8 SL	0.4	39.43 (39.01)*	36.66 (37.37)	28.26 (28.94)	34.78 (36.09)
T_2	Lambda cyhalothrin 5 EC	1	35.89 (36.95)	23.21 (28.75)	12.5 (12.86)	23.87 (28.77)
T_3	Spinosad 45 SC	0.4	43.24 (41.19)	38.56 (38.98)	32 (31.94)	37.93 (37.98)
T_4	Dimethoate 30 EC	3	47.88 (43.65)	44.82 (42.00)	37.5 (38.89)	43.40 (41.19)
T_5	Malathion 50 EC	2.5	54.76 (47.51)	50 (44.81)	42.85 (43.45)	49.20 (44.54)
T_6	Buprofezin 25 SC	2	59.15 (50.66)	56.89 (48.78)	50 (50.46)	55.35 (48.08)
T_7	Thiamethoxam 25WG	0.4	60.25 (51.49)	55.55 (48.27)	52.17 (52.08)	55.99 (48.45)
T_8	Deltamethrin 2.8 EC	0.5	54.54 (47.69)	50 (45.09)	45.83 (45.77)	50.12 (45.07)
T_9	Azadirachtin 0.03%	3	37.5 (37.64)	25 (30.17)	13.04 (13.43)	25.18 (29.64)
T_{10}	*Beauveria bassiana* WP 2%	20	60.97 (51.48)	57.57 (49.11)	56.52 (56.55)	58.35 (49.81)
T_{11}	Untreated control	--	66.66 (54.65)	70 (57.19)	76.47 (76.42)	71.04 (57.50)
SE (m)			2.93	2.53	1.88	1.80
CD 5%			8.67	7.48	5.57	5.32
CV %			11.15	10.26	8.31	7.35

* Figures in the parentheses are arcsine transformed values

Table 2: Benefit cost ratio of insecticides application against fruit fly *Bactrocera dorsalis* in mango

Name of insecticide	Dose (ml or g/L)	Mean yield (kg/plant)	Additional income over control (Rs/tree)	Cost of insecticide (Rs/tree)	Total cost of cultivation (Rs/tree)	Gross monetary returns (Rs/tree)	Net monetary return (Rs/tree)	Benefit Cost Ratio (BCR)	ICBR
Imidacloprid 17.8 SL	0.4	10.7	567	16.8	366.8	1070	703.2	2.91	33.75
Lambda cyhalothrin 5 EC	1	13.07	804	21.6	371.6	1307	935.4	3.51	37.22
Spinosad 45 SC	0.4	8.09	306	171.43	521.43	809	287.57	1.55	1.78
Dimethoate 30 EC	3	7.75	272	54	404	775	371	1.91	5.03
Malathion 50 EC	2.5	7.26	223	30	380	726	346	1.91	7.43
Buprofezin 25 SC	2	6.77	174	17.28	367.28	677	309.72	1.84	10.06
Thiamethoxam 25WG	0.4	5.63	60	10.56	360.56	563	202.44	1.56	5.68
Deltamethrin 2.8 EC	0.5	7.46	243	7.2	357.2	746	388.8	2.08	33.75
Azadirachtin 0.03%	3	12.05	702	46.8	396.8	1205	808.2	3.03	15.00
Beauveria bassiana WP 2%	20	5.83	80	24	374	583	209	1.55	3.33
Untreated control	--	5.03	0	0	350	503	153	1.43	--

Cost of cultivation = 350 Rs/tree
Selling price of mango= 100 Rs/kg

Conclusion
Mango is one of the most consumed tropical fruits worldwide, owing to its taste and high nutritive value, it is grown as both homestead and commercial crop. So there is a need for accounting the plant protection measures to ensure the better production of the crop. Field experiment on bio-efficacy of insecticides against mango fruit fly revealed that three sprays of lambda cyhalothrin 5 EC @ 25 g a.i/ha, one at maturity stage and other 10 days after resulted in significant reduction of fruit infestation over rest of the treatments. The treatment azadirachtin 0.03%, 3 ml/l were also at par lambda cyhalothrin 5 EC. This may be due to the olfactory deterrence of neem spray wards off and disorients the females of fruit fly preventing oviposition and infestation. This treatment was residue free, cost effective and ecologically viable control method that farmers can adopt.

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