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Evaluation of different insecticides and methyl eugenol trap for the management of fruit fly in mango var. Amrapali and its fruit quality assessment

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Abstract
Considerable loss occurs in the marketable yield of mango due to occurrence of fruit flies which may go up to 80 per cent at times. Therefore, to have a better management of the insect a field trial on evaluation of different insecticides sprays in combination with methyl eugenol trap was carried out at Horticultural Research Station, Orissa University of Agriculture and Technology, Bhubaneswar. Out of seven treatments involving ME traps, different chemical insecticides, bio-insecticides in different combinations and a control both without ME trap and insecticides for the insect management, the treatment deltamethrin along with ME trap proved the best with a lowest trap catch of adult fruit flies (23.33/week), lowest percentage infestation of fruits (1.85 per cent) and extent of infestation (2.50 maggots/fruit). In comparison to healthy fruits the infested fruits also had a considerable decrease in TSS, reducing sugar, non-reducing sugar and considerable increase in total acidity content. The economic analysis of the experiment indicated highest net return and benefit-cost ratio from the treatment deltamethrin application and ME trap largely through reduction of fruit infestation up to 76.85 per cent.

Keywords: Amrapali, methyl eugenol trap, mango, insecticides, fruit flies, maggots

1. Introduction

Mango (*Mangifera indica* L.) belongs to the family Anacardiaceae and is one of the most popular fruit crops in the tropical and sub-tropical region of the world. It is termed as the "King of fruits" owing to its delicious taste, captivating flavor and attractive aroma, besides being an excellent source of vitamin A and C. Fruit flies are major pests in several fruit and vegetable crops throughout the tropics and subtropics. Yield loss of up to 80 per cent in mango due to fruit fly infestation has been reported by Abdullah *et al.* (2002) [1] and Mann (1996) [8]. Being polyphagous pests with high reproductive potential, wide host range, overlapping of generations and adaptability to climate, their management is quite difficult. Most common species of fruit fly infesting mango fruits are *Bactrocera dorsalis* Hendel, *Bactrocera correcta* Bezzi and *Bactrocera zonata* Saunders as reported by Verghese and Sudha Devi (1998) [20]. However, *Bactrocera dorsalis* is one of the most destructive fruit fly species for mango. Damage of fruits occurred through oviposition by the adult fruit flies and the larvae tunnel inside the fruit, contaminate the pulp with frass, which predisposes the fruits to fungi and bacteria attack. The affected fruits drop down prematurely, leading to severe reduction in mango yield. The presence of fruit fly larvae in fruits also causes a number of changes in internal quality parameters such as the TSS, pH, percentage titratable acidity. Among the various alternate strategies available for the management of fruit flies, the used of several traps like methyl eugenol traps, traps baited with banana, colored traps have been found encouraging (Jalaluddudin *et al*., 1998) [7]. However, of all these, methyl eugenol trap emerges as the most outstanding. It 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) [12]. Apart from methyl eugenol traps, present management strategies also focus on chemical insecticides. Thus, taking all these into account the experiment was conducted with the objective to evaluate the efficacy of insecticides with methyl eugenol trap in the management of fruit fly and also to study the loss of quality of fruit fly affected fruits.

2. Material and Methods

The experiment was carried out at Horticultural Research Station, Orissa University of

Agriculture and Technology, Bhubaneswar during the year 2018. There were seven treatments comprising of five different insecticidal sprays and methyl eugenol trap and a control without any trap or insecticidal spray, the details of which are as: T_1: Methyl Eugenol trap + Malathion 50 EC (2ml/l), T_2: Methyl Eugenol trap + Cartap Hydrochloride 50 SP (1 g/l), T_3: Methyl Eugenol trap + Deltamethrin 2.8 EC (1 ml/l), T_4: Methyl Eugenol trap + Fipronil 5 SC (1.5 ml/l), T_5: Methyl Eugenol trap + Azadirachtin 300 ppm (2 ml/l), T_6: Methyl Eugenol trap only, T_7: Control (no trap and no spray) arranged in a Randomized Block Design. Installation of traps was started from 18th standard week (SW) till harvest. The traps (Stonehouse *et al*., 2002) [17] were made by using a plywood wooden block of size 5cm x 5cm x 1cm and impregnated with a 6:4:1 mixture by volume of ethyl alcohol, methyl eugenol (4-allyl-1,2-dimethoxy benzene-carboxylate) and malathion 50 EC. The plywood block was soaked in the mixture for a week. Then the blocks were drained and dried in shade for two days. The blocks were fixed inside transparent plastic jars of one litre capacity (14 cm height and 13 cm diameter) in the center by plastic thread to avoid wetting through rains. The jars were punctured with 2 cm holes at 4 places for the entry of flies. Traps were tied in the branches of good flower and fruit bearing plant at the rate of one trap for three plants in each treatment at a height of 0.9 m and were renewed at one-month interval and maintained till harvest. During the later phase of fruit development when the fruits become susceptible to fruit fly attack different insecticides (both chemicals and botanical) were used to sprays the field. Several parameters like mean trap catch of fruit fly in sprayed plot from 18th SW to harvest, number and weight of affected fruits, number and weight of healthy fruits, percentage of affected fruits, extent of infestation by counting the number of maggots emerged from the infested fruits, extent of infestation at 4 week before harvest (WBH), 2 WBH and at harvest for correlation studies were collected and data were subjected to statistical analysis. The cost benefit ratio was worked out by the following formula:

$$\text{Benefit: cost ratio} = \frac{\text{Gross return}}{\text{Total cost of cultivation}}$$

3. Results and Discussion

3.1 Effect of insecticides on the trap catch

The spraying of insecticides had a distinct bearing on the trap catch of fruit flies in mango cv. Amrapali as is evident in Table 1. The mean trap catches of adult flies per week taken as an average over all the SW ranged from a minimum of 23.33 to a maximum of 50.33. All the insecticides are found to exert a significant difference among themselves in respect of the trap catches of fruit fly per week. In absence of any insecticides only ME trap could catch 50.33 fruit flies per trap per week whereas the incidence decreased in the order, azadirachtin, malathion, cartap hydrochloride, fipronil and deltamethrin with catches of 44.67, 36.33, 31.67, 27.67 and 23.33, respectively. There was a reduction of 53.46 per cent in the mean trap catch of fruit fly over Methyl eugenol trap alone. The application of deltamethrin resulting in the minimum infestation of fruits may be due to its efficacy in managing the adult flies as also been reported by Singh (1997) [15].

Table 1: Effect of insecticides on the trap catch of fruit fly in mango, cv. Amrapali

Treatment		Mean trap catch/ week (average of all std weeks)
T_1	Methyl eugenol trap + Malathion 50 EC (2 ml/l)	36.33 (6.03)
T_2	Methyl eugenol trap + Cartap Hydrochloride 50 SP (1 g/l)	31.67 (5.62)
T_3	Methyl eugenol trap + Deltamethrin 2.8 EC (1 ml/l)	23.33 (4.83)
T_4	Methyl eugenol trap + Fipronil 5 SC (1.5 ml/l)	27.67 (5.26)
T_5	Methyl eugenol trap + Azadirachtin 300 ppm (2 ml/l)	44.67 (6.68)
T_6	Methyl eugenol trap only	50.33 (7.09)
SE m (±)		0.13
C.D. (0.05)		0.39

(Figures in the parentheses are square root transformed values)

3.2 Percentage of fruit fly infestation (No. and weight)

The Table 2 indicated the percentage of infested fruits by number and weight. Treatment (T_3) (3.43 percent) resulted in significantly lowest percentage of infested fruits and the control treatment T_7 (11.85 per cent) significantly the highest followed by T_6 (7.79 percent). The treatment T_1, T_2, T_4 and T_5 are found to be at par with each other. The best treatment i.e. T_3 resulted in a significant reduction of 71.06 percent in comparison to the control. With respect to weight of infested fruits, there is a distinct difference in weight recorded from different treatments while the control i.e. without ME trap and without insecticidal sprays recorded significantly highest percentage of infestation (7.99 percent) the minimum was recorded in T_3 (1.85 percent). However, the treatment T_4 and T_2 were at par with T_3. T_6 (with only ME traps) recorded significantly lower percentage (5.53 percent) of infestation than the control and significantly higher (5.53 percent) than other insecticidal sprays. Spraying with malathion (T_1) was found to be an intermediate treatment (2.55 percent) between azadirachtin sprays (5.53 percent) and other insecticidal sprays. The treatment T_7 i.e. without ME traps and without sprays recorded the highest percent fruit infestation. The best treatment i.e. T_3 resulted in a significant reduction of infestation by 66.55 and 76.84 per cent over treatment with only ME trap and control, respectively.

Table 2: Percentage of fruit fly infestation in mango, cv. Amrapali (Number and weight)

Treatments	No. of infested fruits/plant	No. of harvested fruits/plant	% Infestation	Weight of infested fruits (kg/plant)	Weight of harvested fruits (kg/plant)	% Infestation
T_1	7.67	122.33	5.92 (2.43)	0.49	18.81	2.55 (1.60)
T_2	7.33	134.00	5.22 (2.28)	0.45	20.56	2.16 (1.46)
T_3	5.55	154.00	3.43 (1.85)	0.45	23.72	1.85 (1.36)
T_4	6.78	139.00	4.76 (2.16)	0.45	21.49	2.11 (1.44)
T_5	8.11	116.22	6.43 (2.51)	0.68	18.00	3.63 (1.90)
T_6	8.67	102.78	7.79 (2.79)	0.91	15.72	5.53 (2.34)
T_7	10.11	76.56	11.85 (3.44)	0.99	11.68	7.99 (2.82)
SE m(±)	-	7.96	0.15	-	1.24	0.10
C.D. (0.05)	-	24.52	0.45	-	3.83	0.31

(Figures in the parentheses are square root transformed values)

The percent fruit infestation is indirectly related to the efficacy of the insecticides evaluated. Lower the infestation of fruits, higher is the efficacy of the insecticide and vice-versa. These findings are in accordance with the results of Dale and Patel (2010) [4] who recorded the lowest per cent infestation by fruit fly in the treatment where deltamethrin was sprayed on the plants. Similarly, Tandon and Verghese (1996) [18] also made a similar finding where they reported deltamethrin to be the most effective insecticide in managing fruit fly population in mango. Likewise, Sood and Sharma (2004) [16] reported significantly less fruit infestation by cucurbit fruit fly in treatments with pyrethroids (deltamethrin, cypermethrin and fenvalerate) in comparison to malathion.

3.3 Extent of fruit fly infestation in mango cv. Amrapali

The Table 3 indicated the data regarding the extent of fruit infestation in mango cv. Amrapali by fruit flies. The data showed that the mean number of maggot emergence per fruit range from 2.50 percent in T_3 to 3.18 percent in T_7. Lower mean number of maggot emergence was observed in the treatments T_2, T_3 and T_4 in comparison to T_7 which were at par with one another whereas the treatments T_5, T_6 and T_7 recorded higher mean number of maggot emergence and were statistically par with one another. Deltamethrin being a synthetic pyrethroid emerged as the best insecticide in exerting a significant controlling effect upon the fruit infestation. Other insecticides resulting a significant reduction in the maggot emergence for fruit was fipronil with 2.68 maggots emerging from the fruit. In this respect, safer insecticide like malathion and biopesticide like azadirachtin were not very effective in controlling the infestation by fruit flies. The present finding is in agreement with Shukla *et al*. (1984) [14] who tested seven insecticides against *Bactrocera* and reported deltamethrin 0.0025 per cent to be the most effective one in comparison to others.

Table 3: Extent of fruit fly infestation in mango, cv. Amrapali (maggots' emergence/fruit)

Treatment		Mean no. of maggot emergence/fruit
T_1	Methyl eugenol trap + Malathion 50 EC (2 ml/l)	2.80 (1.67)
T_2	Methyl eugenol trap + Cartap Hydrochloride 50 SP (1 g/l)	2.72 (1.65)
T_3	Methyl eugenol trap + Deltamethrin 2.8 EC (1 ml/l)	2.50 (1.58)
T_4	Methyl eugenol trap + Fipronil 5 SC (1.5 ml/l)	2.68 (1.64)
T_5	Methyl eugenol trap + Azadirachtin 300 ppm (2 ml/l)	2.90 (1.70)
T_6	Methyl eugenol trap only	3.00 (1.73)
T_7	Control	3.18 (1.78)
SE m(±)		0.03
C.D. (0.05)		0.08

(Figures in the parentheses are square root transformed values

3.3 Correlation between quality parameters and extent of infestation

The extent of fruit infestation and biochemical constituents at different stages of fruit development and maturity were observed and presented in Table 04 and 05. The incidence of fruit fly infestation increases in the later part of fruit development and towards ripening from 1.4 (4WBH) to 5.2 (at harvest) maggots per fruit. The TSS and total sugar increases with maturity while acidity, fruit firmness and peel thickness decrease with ripening. Population of *B. dorsalis* at different stages of the crop when monitored using bait trap and ME trap revealed that the population was minimum at flowering stage, increased significantly during fruit set and reached its peak in the fruit ripening stage in May-June (Reji Rani *et al*., 2012) [11]. Rattanapun *et al.* (2009) [10] examine the influence of different ripening stages of mango *Mangifera indica* L. by female *B. dorsalis* and endorse the present findings that ripe and fully-ripe mangoes were most preferred for oviposition than immature fruits by the pests.

Table 4: Extent of infestation by fruit fly in mango, cv. Amrapali at different stages of fruit development (maggots present in the pulp/fruit)

Stage of fruit development	Extent of infestation (No. of maggots present in fruit pulp)
4 WBH	1.4
2WBH	3.0
At harvest	5.2

Table 5: Quality parameters of mango, cv. Amrapali fruits at different stages of development

Character	Stage of harvest	Value
TSS (° Brix)	4 WBH	6.5
	2 WBH	8.3
	Harvest stage	11.2
Total sugar (%)	4 WBH	2.56
	2 WBH	3.08
	Harvest stage	4.12
Acidity (%)	4 WBH	0.784
	2 WBH	0.582
	Harvest stage	0.351
Fruit firmness (kg/cm^2)	4 WBH	1.72
	2 WBH	1.48
	Harvest stage	1.20
Peel thickness (mm)	4 WBH	2.54
	2 WBH	2.32
	Harvest stage	1.98

Table 6: Correlation between quality parameters and extent of infestation in mango, cv. Amrapali

	TSS	Total Sugar	Total Acidity	Fruit Firmness	Peel Thickness
Extent of infestation	0.999058*	0.995082	-0.99863*	-0.99892*	-0.99948*

The extent of infestation in fruits of cultivar Amrapali has been evaluated at harvest, 2WBH and 4WBH and presented in Table 4. The quality parameters, namely, TSS, total sugar, acidity, fruit firmness and peel thickness have been analysed and presented in Table 05. Correlation studies were carried out using the values in Table 4 and 5 and presented in Table 6. The correlation data showed that the extent of fruit infestation was significantly correlated with four characters out of which total soluble solid was positively (r = 0.999058) and total acidity, fruit firmness and peel thickness were negatively correlated (r = -0.99863, -0.99892 and -0.99948, respectively) with extent of infestation. With respect to total sugar, a non-significant and positive correlation was observed with the extent of infestation of the fruits by fruit fly maggots. This finding is in line with the results of Venkata Rami Reddy and Vasugi (2008) [19] who reported a significantly positive correlation between TSS and fruit fly infestation and a significantly negative correlation with total acidity in guava. Arora *et al.* (2000) [3] also reported a similar trend of correlation between fruit fly incidence and TSS in guava. With respect to fruit firmness and peel thickness, the present result showed a significantly negative correlation with fruit fly infestation which means lower the firmness of the pulp and peel thickness higher is the preferences for oviposition by the female fruit fly adults. Studies made by Rossetto *et al.* (2006) [13] and Rattanapun *et al*. (2009) [10] showed that fruit firmness and thickness greatly affected the oviposition preference of fruit flies, with female tephritids having oviposition preference for fruits with softer pericarp over those with harder pericarp. Similarly, Nandre and Shukla (2013) [9] studied the effect of chemical constituents of fifteen sapota germplasm collections against fruit fly infestation and reported that the fruit fly infestation had significant positive correlation with total soluble solids (TSS) and total sugars whereas, it had negative correlation with acidity. Ibrahim and Rahman (1982) [6] found that when a food resource was too acidic, many larvae of *Bactrocera dorsalis* failed to pupate, and that even if they successfully pupated, the pupae were lighter and smaller in size. Thus, the present findings are in agreement with these observations.

3.4 Biochemical parameters in fruit fly infested and non-infested fruits

The data in the table 7. showed that there is a decrease in the values of TSS, reducing sugar, non-reducing sugar while an increase in acidity was observed in the fruit fly infested fruits in comparison to the non-infested fruits. The decrease in TSS, reducing sugar and non-reducing sugar were to the tune of 17.96, 8.33 and 16.54 per cent, respectively, while the increase in acidity was to the extent of 41.40 per cent in the infested fruits. The present results are in accordance with the findings of Akoto *et al.* (2011) [2] who reported higher TSS and pH and lower acidity in healthy fruits whereas lower TSS and higher acidity in fruit fly infested fruits. The reduction in pH and total sugars and increase in acidity could be as a result of the feeding activity of the larvae which converted most of the carbohydrates in the fruit to acid (Dea *et al*., 2010) [5].

Table 7: Comparison of biochemical parameters of fruit fly infested and non-infested fruits in mango, cv. Amrapali

Biochemical parameters	Infested fruits	Non infested fruits
TSS (^{0}Brix)	12.654	15.425
Reducing sugar (%)	2.464	2.688
Non reducing sugar (%)	4.161	4.986
Total sugar (%)	6.845	7.936
Total Acidity (%)	0.362	0.256

3.5 Economic analysis

The total cost of cultivation, the differential cost of cultivation, total return and the net return in different treatments have been calculated and summarized in Table 8. The economic data showed that the differential cost of cultivation range from a minimum of Rs. 0 ha^{-1} in the control treatment (T_7) to a maximum of Rs. 2218 ha^{-1} in both T_2 and T_4. Similarly, the total cost of cultivation ranges from a minimum of Rs. 88000 ha^{-1} in T_7 to a maximum of Rs. 90218 ha^{-1} in both T_2 and T_4. The yield of fruits from different treatments ranged from a minimum of 4.67 t ha^{-1} in T_7 to a maximum of 9.49 t ha^{-1} in T_3. A spray of deltamethrin (T_3) resulted in an increase in yield of 50.87 and 103.21 per cent over T_6 and T_7, respectively. The total return ranged from lowest of Rs. 93400 in T_7 to a highest of Rs. 189800 in T_3. The net returns from different treatments ranged from a minimum of Rs. 5400 ha^{-1} to a maximum of Rs. 99972 ha^{-1}. Following a similar trend, the benefit cost (B:C) ratio ranges from 1.06 to 2.11. The net return from different treatments varied widely. It was as low as Rs. 5400 ha^{-1}. It increases to a maximum of Rs. 99972 ha^{-1} under the treatment with ME trap and deltamethrin application. T_6 with only ME trap.

Table 8: Economics of different treatments

Treatment	% infestation	Yield (ha^{-1})	% increase yield over control	Total cost (ha^{-1})	Differential cost of cultivation (ha^{-1})	Total return (ha^{-1})	Net return (ha-1)	B:C ratio
T_1	2.55 (1.60)	7.52	61.04	89908	1908	150400	60492	1.67
T_2	2.16 (1.46)	8.22	76.03	90218	2218	164400	74182	1.82
T_3	1.85 (1.36)	9.49	103.08	89828	1828	189800	99972	2.11
T_4	2.11 (1.44)	8.60	83.99	90218	2218	172000	81782	1.91
T_5	3.63 (1.90)	7.20	54.11	89988	1988	144000	54012	1.60
T_6	5.53 (2.34)	6.29	34.59	88118	118	125800	37682	1.43
T_7	7.99 (2.82)	4.67	0.00	88000	0	93400	5400	1.06
C. D. (0.05)	0.31	1.532						

*Sale price of mangoes = Rs. 20000 t^{-1},

resulted in Rs. 37680 ha^{-1}. The B:C ratio was also reflected in a similar way with a value of 1.06 in T_7 and 2.11 in T_3. Net profit was highest (Rs. 99972 ha^{-1}) in T_3 which is due to the maximum efficacy of the synthetic pyrethroid deltamethrin. It is pertinent to say that the two chemical insecticides cartap hydrochloride and fipronil though incurred higher cost of the insecticides (Rs. 750 ha^{-1} in each) were not able to reduce the percentage of infestation and therefore could not result in higher yield and subsequent return in comparison to deltamethrin (Rs. 360 ha^{-1}). Different workers have reported different net returns and B:C ratios depending on the different insecticides used and locations of study.

4. Conclusion

The infestation of fruits can be controlled efficiently by the combined use of deltamethrin 2.8 EC (1ml/l) + ME traps towards the time of maturity in mango cv. Amrapali. For getting maximum net returns of Rs. 99972 ha^{-1} and highest B:C ratio of 2.11 the same treatment may be taken up around the fruit maturity time in mango cv. Amrapali.

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