Yield and Fruit Quality Loss as Affected by Fruit Fly in Mango (*Mangifera indica* L.)

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(Fruit Science and Horticulture Technology)

By

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CERTIFICATE-I

This is to certify that the thesis entitled **"YIELD AND FRUIT QUALITY LOSS AS AFFECTED BY FRUIT FLY IN MANGO (*Mangifera indica* L.)"** submitted in partial fulfillment of the requirements for the award of the degree of **MASTER OF SCIENCE IN AGRICULTURE (FRUIT SCIENCE AND HORTICULTURE TECHNOLOGY)** to the Orissa University of Agriculture and Technology is a faithful record of *bona fide* and original research work carried out by **LHINGNEIVAH CHONGLOI** under my guidance and supervision. No part of this thesis has been submitted for any other degree or diploma.

It is further certified that the assistance and help received by her from various sources during the course of investigation has been duly acknowledged.

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CERTIFICATE-II

This is to certify that the thesis entitled **"**YIELD AND FRUIT QUALITY LOSS AS AFFECTED BY FRUIT FLY IN MANGO (*Mangifera indica* L.)**"** submitted by **LHINGNEIVAH CHONGLOI** to the Orissa University of Agriculture and Technology, Bhubaneswar in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN AGRICULTURE (FRUIT SCIENCE AND HORTICULTURE TECHNOLOGY)** has been approved by the students' advisory committee and external examiner.

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CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS USED

%	:	Per cent
/	:	Per
@	:	At the rate
a.i.	:	Active ingredient
C.D.	:	Critical Difference
cm	:	Centimeter
SP	:	Soluble powder
et al.	:	And others
etc.	:	Etcetera
g	:	Gram
ha	:	Hectare
Hrs.	:	Hours
i.e.	:	(*Id est.*) that is
Kg	:	Kilogram
ME	:	Methyl eugenol
m	:	Meter
Max.	:	Maximum
Min.	:	Minimum
EC	:	Emulsifiable concentrate
mm	:	Millimeter
mg	:	Milligram
No.	:	Number
R.H.	:	Relative humidity
SEm	:	Standard error of mean
SW	:	Standard week
B: C	:	Benefit-cost
SC	:	Soluble concentrate
T	:	Tonnes
Viz.	:	(*Videlicet*) Namely
WBH	:	Week before harvest
°C	:	Degree Celsius

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. The degree of infestation becomes more as the fruits are affected by both adults and maggots. Therefore, to have a better management of the insect a field trial "Yield and Fruit Quality Loss as Affected by Fruit Fly in Mango (*Mangifera indica* L.)" was conducted at Horticultural Research Station, Orissa University of Agriculture and Technology, Bhubaneswar. Among the different varieties grown during 2017 Dashehari recorded a minimum mean trap catch of 11.50 adult fruit flies per week and Totapuri a maximum of 104.25 mean trap catch per week during their peak periods. The incidence of fruit flies had a significant and positive correlation with maximum and minimum temperature and significantly negative correlation with morning relative humidity when monitored during the fruit development and maturity period in 2017. 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 arranged in a Randomized Block Design, 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). The biochemical parameters such as TSS, total sugar, total acidity, fruit firmness and peel thickness had significant correlations with the extent of infestation by fruit flies. 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.

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. Out of the several species under genus *M. indica* is the only species that is grown commercially on a large scale. There are more than 1,100 varieties of mangoes grown around the world (Griesbach, 2003).

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. The ripe fruit is not only eaten fresh, but it is also utilized for processing into various products like canned mango slices in syrup, pulp, jam, squash, juice, nectar, cereal flakes, mango custard powder, mango toffee, mango leather, and mango juice powder. Unripe mango fruits are also used for preparing various products like mango pickle, chutney, brined mango slices and powder, mango wine and other delicacies.

With respect to area and production, India is the second largest producer of fruits in the world with an annual production of 93.70 million tons from an area of 6.45 million hectares out of which mango accounts for 20.29 million tons from an area of 2.26 million hectares (NHB, 2017).In spite of India’s top position in mango production, it exports less than one per cent of the produce. Quarantine of plant produce has emerged as one of the biggest reasons for the low quantity of mango exports.

Fruit flies are major pests in several fruit and vegetable crops throughout the tropics and subtropics. Nearly 35% of the known fruit fly species attack soft fruits of which mango, guava, citrus, ber, peach and several cucurbitaceous vegetables are important (White and Elson-Harris 1992).

The mango fruit fly is believed to be the single largest crop damager in India. It accounts for about 27 per cent of harvesting loss. The flies attack semi ripe and mature fruits during the months of April and May. Other fruits like guava, citrus, plum, peach, sapota, loquat, etc. are also susceptible to this pest attack. Damage is caused both by adults and maggots of the insect. Adult female punctures the rind of near ripe fruit with its needle like ovipositor and lays eggs.

Yield loss of up to 80 per cent in mango due to fruit fly infestation has been reported by different workers (Abdullah *et al.*, 2002: Mann, 1996). Hence, it is regarded as a pest of quarantine importance.

Bactrocera dorsalis Hendel (oriental fruit fly) is reported to cause 100.0, 87.0, 78.0 and 61.0 % fruit damage in rainy season in guava, mango, peach and pear, respectively (Sharma et *al.*,2011a), whereas, Singh (2010) reported significant losses in Kinnow due to fruit flies. The damage on crops caused by oriental fruit flies resulted from oviposition in fruit, feeding by the maggots and decaying of tissue by invading secondary microorganisms that leads to fruit drop.

Bactrocera, a major genus of fruit flies involves different species, namely, *B. dorsalis, B. cucurbitae, B. correcta and B. zonata. B. cucurbitae* is a major pest of almost all cucurbits and damages up to 70% of the fruits (Kapoor, 2002).

Fruit fly being a high priority quarantine pest, India has been included in the list of those countries from where fruit import to developed countries is banned. In India a total loss of 2,558 and 26,902 million rupees were estimated due to fruit flies with and without control measures, respectively (Stonehouse, 2001).

Fruit flies belong to the family Tephritidae which is one of the largest, most diversified and fascinating acalypterate families of Diptera. Species under family Tephritidae are commonly called "fruit flies" due to their close association with fruits and vegetables. Out of 4000 species under the family 392 species have been recorded in India (Kapoor, 1993).

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 (Verghese and Sudha Devi, 1998). However, *Bactrocera dorsalis* is one of the most destructive fruit fly species.

The flies attack the fruits at different stages of maturity. Damage occurs through oviposition on the fruits, resulting in the formation of black or brown necrosis (lesions) around the puncture marks, followed by decomposition of the fruit especially from the internal feeding of the larvae (CABI, 1999). 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, since the maggots after emergence from the fruits start boring into the fruits causing fruit drop before they come to maturity, leading to severe reduction in mango yield. The damage is more evident after harvest, when the fruits are infested at maturity stage. Hence, delayed harvesting makes the fruits vulnerable to the attack of fruit flies creating major problems in their export.

The losses in fruit quality deprive communities of an important source of nutrition (particularly vitamin A) and lead to the loss of highly valuable market shares when quarantine sensitive importing countries refuse produce because of the potential threat of these flies. The presence of fruit fly larvae in fruits causes a number of changes in internal quality parameters such as the TSS, pH, percentage titratable acidity and the internal damage area.

Commercial mango growers in the country often resort to indiscriminate use of toxic pesticides leading to pesticide residues in the harvested fruits. The large scale use of synthetic insecticides in the past has resulted in various ecological disturbances and resistance in insect pests. So, now-a-days there is increasing awareness among the farmers about the side effects of synthetic pesticides. However, in heavy infestation of the pests one has to rely on synthetic insecticides in order to get immediate and effective results.

Among the various alternate strategies available for the management of fruit flies, the uses of several traps have been found encouraging. Among them methyl eugenol traps, traps baited with banana, coloured traps to attract both males and female insects are noteworthy (Jalaluddudin *et al*., 1998). However, of all these, methyl eugenol trap emerges as the most outstanding. This chemical has been used by many workers to monitor the fruit fly incidence in different crops (Madhura, 2001). Such traps are also used to determine the seasonal distribution and abundance of adult population of *Bactrocera dorsalis*. 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). The use of methyl eugenol traps have been considered very effective in recent times since their use involves minimum environmental pollution. Apart from methyl eugenol traps, present management strategies also focus on chemical insecticides. Mango growers rely on chemical control measures for successful management of fruit flies including cover sprays, bait sprays etc. with organophosphate insecticides like malathion as toxicant. Use of organophosphorus compounds, pyrethroids and antibiotic insecticides to reduce the damage of *B. dorsalis* are still considered the main control measures. Keeping these findings in view, the present investigation on “Yield and Fruit Quality Loss as Affected by Fruit Fly in Mango (*Mangifera indica* L.) was undertaken with the following objectives.

1. Ascertain the seasonality of fruit fly incidence
2. Study the loss of quality of fruit fly affected fruits
3. Evaluate the efficacy of insecticides in the management of fruit fly

REVIEW OF LITERATURE

In the present chapter of the thesis entitled “Yield and Fruit Quality Loss as Affected by Fruit Fly in Mango (*Mangifera indica* L.)” several attempts have been made to present a brief account of the previous research findings in the form of review under the following heads. There are several research work conducted by different scientific workers. This chapter mainly provides good guidelines to carry out research work.

2.1. Occurrence of fruit fly in India

Two hundred species of fruit flies are known from India. Not all of them are pests. Only 35 to 40 species are so far associated, directly or indirectly, with their host plants. *B. dorsalis* occurs in a complex of at least four species; of these only the true *B. dorsalis* is of greatest importance but *B. zonata* has now surpassed *B. dorsalis* in many mango growing areas. It is believed to occur in a complex of two to three species. Both *B. zonata* and *B. dorsalis* compete strongly with *B. correcta* in guava in some important fruit-growing areas in India, which sometimes becomes a major threat (Kapoor, 2002).

Verghese *et al*. (2002) reported 200 species of fruit flies in India which is about 5% of the known tephritid fauna of the world. From an economic point of view, *Bactrocera dorsalis* (Hendel), *B. correcta* (Bezzi), *B. zonata* (Saunders) and *B. cucurbitae* (Coquillett) are important. The first three species mainly attack fruit crops, while *B. cucurbitae* attacks different species of cucurbits. *B. dorsalis* is a major fruit fly pest, especially on mango, affecting local and export markets.

2.2 Seasonality of fruit fly incidence

2.2.1 Temperature

The influence of weather parameters and host plant on the abundance and population of fruit fly in mango were studied by Kannan and Rao, (2006). The peak incidence of fruit fly activity was observed during last week of May (6 to 9 infested fruits/20 fruits). However, a gradual increase was observed during first week of April (24 infested fruits/20 fruits) and declined during fourth week of June (5.5 infested fruits/20 fruits). Correlation studies between incidence and weather parameters showed significant positive relationship with maximum and minimum temperatures and negatively correlated with rainfall and relative humidity.

Ranjitha and Viraktamath (2006) reported that population of *B. dorsalis* which was 8.33 fruit flies/trap during 27th standard week in 2003, reached a major peak of 22.47 fruit flies during 30th standard week. Later the population declined and remained at a low level with slight fluctuations. The population of *Bactrocera* sp. had positive correlation with minimum temperature and rainfall, negative correlation with relative humidity and a positive non-significant correlation with maximum temperature.

A field experiment was carried out at Navsari Agricultural University, Navsari during 2009 to 2011. Population of fruit fly was observed during 13th (26 March-1 April) to 30th (23 July-29 July) standard week (SW) in the year 2009-10 and 2010-11 and pooled. Highest fruit fly infestation (36.67%) was observed in 22nd SW coinciding with ripening cum harvesting period of mango which increases with increase in temperature, relative humidity, wind velocity and evaporation (Patel *et al*., 2013).

An experiment conducted by Fadlelmula and Ali (2014) at Blue Nile State Sudan, for two consecutive seasons 2009-10 and 2010-11, in two orchards of mango located at Damazine for seasonal abundance studies using methyl eugenol trap showed that *B. invadens* population level was low during March-May in mango orchard. The population peaks appeared in June-July, December and January depending on the temperature, rainfall and availability of the mango fruits Mishra *et al*. (2014) reported that *B. dorsalis* population showed its peak in 32nd and 35th standard week, respectively. Correlation between *B. dorsalis* and weather conditions resulted in a non-significant correlation with maximum temperature while it showed positive significant correlation with minimum temperature, relative humidity and rainfall in two years of the experiment.

Studies were made on seasonal activity and effect of weather parameters on population dynamics of fruit flies in mango orchard during 2008-09 at GKVK campus, Bangalore by Nagaraj *et al*. (2014a). Monitoring studies on seasonal activity revealed occurrence of *B. dorsalis*, *B. correcta* and *B. zonata* throughout the year in mango orchard. Fruit flies had two major peaks during second and third week of July with the mean trap catches of 57.7 and 48.7 fruit flies / trap / week respectively. There was high significant positive correlation between trap catches of *B. dorsalis* and minimum temperature (r=0.546**) morning relative humidity (r=0.558**) and afternoon relative humidity (r=0.562**).

Surveillance of fruit fly populations in mango orchard revealed that peak population of *B. zonata* (40-30 per trap per week) and fruit infestation (9.05-7.45%) were recorded in June, July and August (Sarwar *et al*., 2014).

Stanley *et al*. (2015) studied the population dynamics of fruit flies, *Bactrocera dorsalis, B. zonata* and *B. diversa* through pheromone trap using methyl eugenol in vegetable gardens and orchards of North Western Himalayan hills. The abiotic factors such as temperature, rainfall, relative humidity and host plants with respect to the population dynamics were analyzed to understand the interactions. A unimodal pattern was noticed in all the species studied with peak incidence from May to October. The fruit fly incidence was positively correlated with maximum and minimum temperature, and when the temperatures fall within the optimum range, the population was at its peak.

Occurrence and population dynamics of the fruit fly were compared with meteorological factors, such as temperature, relative humidity and sunshine. The highest mean population of fruit fly remained at 499 in the month of August. It started to decline afterwards to 348 in the month of September. The lowest population was recorded at 26, 3, 2 and 1 for November, December, January and February, respectively. The optimum monthly average temperature and relative humidity ranged from 26 to 35°C and 60%, respectively. The population of the fruit fly was positively correlated with the temperature and slightly negative correlation was seen for relative humidity (Khan and Naveed, 2017).

2.2.2 Rainfall

Vayssieres *et al*. (2009) reported that among the three species of genus Bactrocera, viz. *B. ceratitis, B. cosyra and B. invadens*, the species ceratitis and cosyra population reached their peaks during the dry season and at the end of the dry season, respectively but *B. invadens* population were scarce during the dry season and increased steadily from the end of April to reach a peak at the end of June during the rainy season. Mean damage on mangoes for the two seasons and two studied orchards increased from 17 per cent in early April to 73 per cent in mid June.

A research was carried out to determine the population dynamics and the diversity of fruit flies in a mixed orchard containing the mango (*Mangifera indica*) cultivars Haden, Tommy Atkins and Palmer at Presidente Prudente town, SP, Brazil. The population dynamics of fruit flies was measured from November 2005 to December 2007 by weekly samplings of the adult insects, using yellow-bottomed McPhail traps baited with hydrolyzed protein. The highest densities of fruit flies occurred during the fruit-ripening period (from November to March), which is characterized by increased rainfall levels and high temperatures (Montes *et al*., 2012).

Studies on population dynamics of different fruit flies by using locally made methyl eugenol (ME) traps were conducted by Agrawal and Deepa (2013) at five locations of Kanpur district (U.P.). The incidence of fruit flies was correlated with weather data. Three species viz. *Bactrocera dorsalis* (Hendel), *B. zonata* (Sounders) and *B. correcta* (Bezzi) were captured in the ME Traps, of which *B. correcta* was predominant followed by *B. zonata* and *B. dorsalis*. On population of *B. correcta,* temperature had a positive correlation at three places viz. horticulture orchard, vegetable farm and IIPR while at two places it had negative correlation (r = -0.034 and -0.2811) i.e. at insectary and Vishnupuri, respectively. Relative humidity was negatively correlated at four locations while it showed positive correlation at IIPR (r = 0.273). Rainfall had a positive correlation with catches of *B. correcta* at three locations while it showed positive correlation at two places. *B. zonata* and *B. dorsalis* had a positive correlation with temperature.

2.2.3 Crop phenology

An experiment was carried out by Rattanapun *et al.* (2009) to examine the influence of different ripening stages of mango *Mangifera indica* L. by female *B. dorsalis.* Study revealed that ripe and fully-ripe mangoes were most preferred for oviposition than immature fruits by the pests. Consistent with the results of oviposition preference, ripe and fully-ripe mangoes were also best for offspring survival, with a higher percentage of larval survival to pupation and shorter development time in comparison to unripe mango.

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).

Spread and prevalence of fruit flies were based on the flowering and fruiting phenology of the mango and other host fruit trees. It was in the order of early flowering tracts to late flowering tracts as proved from methyl eugenol trap based fruit fly catches over an ecological distance from the Thrissur (kerala) to Kerala-Tamil Nadu border. The study made by Thiyagarajan *et al*. (2015) showed that fruit fly population recorded an increasing trends from early flowering zone of Muthalamada (Kerala) regions to the late flowering zones of Thrissur (Kerala) regions.

Guillen *et al*. (2017) studied the influence of resin ducts, sap content, and fruit physicochemical features of four mango cultivars (Criollo, Manila, Ataulfo, and Tommy Atkins) on their susceptibility to the attack of the two most pestiferous fruit fly species *Anastrepha ludens* (Loew) and *Anastrepha obliqua* (Macquart) infesting mangoes in Mexico. Ataulfo and Tommy Atkins cultivars exhibited the highest resin duct density and sap content, the lowest infestation rate, and had a negative effect on immature development and pupal weight. It was concluded that sap content and the number, size, and distribution of resin ducts as well as firmness in mango fruit exocarp are all involved in the resistance of mango to *A. ludens* and *A. oblique* attack.

2.2.4 Varietal susceptibility

Kamala Jayanthi and Verghese (2008) An experiment was conducted to evaluate the ovipositional non-preference of *B. dorsalis* to selected polyembryonic variesties of mango viz., EC95862 and Mylupelian through choice and non-choice bioassays. These polyembryonic varieties were found less preferred to standard comparisons showing ovipositional non-preference in both the assays.

The susceptibility of four economically important mango varieties (Kent, Keith, Palmer and Haden) to the attack by *B. invadens* was assessed in Ghana through a series of laboratory-based choice and no-choice experiments. Susceptibility was determined by counting and comparing the number of puparia recovered from the different varieties after exposure to the flies in cages. Result showed that Kent was the most susceptible, followed by Palmer, Haden and Keit (Ambele *et al.*, 2011).

Studies were made by Nagaraj *et al.* (2014b) on monitoring the incidence of fruit fly (*Bactrocera* spp.) using methyl eugenol traps in different mango orchards and varieties during 2008-09 at GKVK campus, Bangalore and Srinivaspur, Kolar. The result revealed that highest number of fruit flies were trapped in Mallika (22.38 fruit flies/trap/week) orchard followed by Banganpalli (18.65 fruit flies/trap/week), while the lowest trap catches were recorded in Alphonso orchard. In laboratory study, evaluation on maggot emergence in different mango varieties showed highest maggot emergence in cv. Mallika (1.40 maggot/fruit) followed by Amrapali (1.00 maggot/fruit).

2.3 Quality loss in fruit fly infested fruits

The pest incidence of fruit fly infestation was correlated with fruit biochemical components, *viz*. total soluble solids (TSS), total sugars, vitamin C and acidity in the wild species of guava. The TSS and total sugars were positively correlated with fruit fly infestation while acidity was negatively correlated (Venkata Rami Reddy and Vasugi, 2008).

Akoto*et al*. (2011) could find the presence of fruit fly larvae in fruits which caused a number of changes in internal quality parameters such as the TSS, pH, per cent titratable acidity and the internal damage area. While pH and TSS decreased with storage time, per cent titratable acidity increased with storage time compared with the controlled fruits where there was an increase in pH and TSS and a decrease in per cent titratable acidity.

An experiment was conducted on four varieties of mango namely, Kent, Keith, Palmer and Haden in Ghana to determine the fruit quality parameters of fruit fly affected samples. Significant differences were observed in the peel thickness, firmness, per cent titratable acidity and total soluble solids of the four varieties (Ambele *et al*., 2011).

As per the studies made by Nandre and Shukla (2013) on the effect of chemical constituents of all 15 sapota germplasm collections against fruit fly infestation revealed that the fruit fly infestation had significant positive correlation with total soluble solids and total sugars whereas, it had negative correlation with acidity. Fruit fly incidence had no significant impact on physical characters, *viz.*, fruit shape and skin pulp ratio. Sapota germplasms with thin fruit skin were more susceptible to fruit fly damage as compared to those with thick skin fruit.

The fruit phenological changes including increasing of total soluble solids(TSS), reduction of fruit juice acidity and fruit firmness factor may play important roles in susceptibility of dropped immature mango fruits to the peach fruit fly attack (Ali Ahmed Amin, 2017).

2.4 Yield loss due to fruit fly infestation

In comparisons of bait application technique (BAT) with farmer controls, average season-end fruit infestation in melon was 29% in unprotected fields and 5% in those protected by BAT; in guava infestation was 44% in unprotected orchards and 12% in orchards protected by BAT; in jujube, infestation was 16% in unprotected orchards and 4% in those protected by BAT; whereas in mango, soaked-block male annihilation technique (MAT) was compared with farmer practices of no control: average infestation before harvest was 9% in unprotected plots and 0% in those protected in an experiment conducted in Pakistan (Stonehouse *et al*., 2002).

Verghese *et al*. (2002) reported in their experiment conducted in Bangalore that the crop loss due to *B. dorsalis in* mango varied from 2.5% to 59.0 % in an unsprayed orchard depending on the variety. The cultivars Dashehari and Langra were least infested, while cultivars Banganpalli and Totapuri had a mean infestation of 46.0 and 59.0%, respectively. In guava they reported a crop loss of between 5% and 70% due to *B. dorsalis*.

Direct damage to mango and guava due to *B. invadens* has been reported by Majacunene *et al*. (2014) to a range from 56.5% to 92.5% in the Northern Province of Cabo Delgado. In addition to the direct losses, indirect losses due to quarantine restrictions have been enormous since the occurrence of *B. invadens* has led to the suspension of fruit and vegetable exports to the country's major trading partners.

2.5. Management of fruit fly

2.5.1 Traps

Studies conducted by Verghese *et al*. (2006) on the commercial variety Banganapalli at the Indian Institute of Horticultural Research, Hessaraghatta during 2004-05 showed that a pre harvest IPM combination of male annihilation technique (using methyl eugenol as a lure) + sanitation brought down *B. dorsalis* infestation to 5.00% from an infestation ranging from 17%– 66% in control in both the years. An additional cover spray of Decamethrin 2.8 EC 0.5ml/l (half of the recommended dose) + Azadirachtin (0.03 %) 2ml/l (neem based botanical) gave 100% control in both the years.

An investigation was carried out in the year 2007-08 to evaluate the performance of eco-trap, methyl eugenol bait and carbaryl against fruit fly in mango. Maximum number of fruit flies were trapped in treatment T_3 (25 trees per eco-trap) followed by T_2 (20 trees per eco-trap) and T_4 (30 trees per eco-trap). Effectiveness of the eco traps was maintained up to 45 days (Singh *et al*., 2009).

Methyl eugenol (ME) and cue-lure (C-L) traps to detect tephritid flies were tested by Vargas *et al*. (2009) in the US with and without insecticides against small populations of oriental fruit fly (*Bactrocera dorsalis*). In comparative tests, standard Jackson traps with naled and the Hawaii fruit fly area wide pest management (AWPM) trap with 2,2-dichorovinyl dimethyl phosphate (DDVP) insecticidal strips outperformed traps without an insecticide.

An area-wide management (AWM) program for citrus and other fruits which includes baits spraying and year-round installation of male annihilation technology (MAT) resulted in overall suppression of fruit fly populations. Male trap catches at the peak activity time were reduced by 95% and overall fruit fly infestation in untreated backyard fruits reduced from 60.8% to 21.8% (Annice *et al.*, 2010).

Rakshak fruit fly trap was found superior to bottle fruit fly trap in an experiment conducted by Pal *et al*. (2012). Maximum fruit flies were trapped when para-pheromones were replenished at one month interval. *Bactrocera zonata* in methyl eugenol baited traps and *B. cucurbitae* in cuelure baited traps were predominant when replenished at one month interval. Bottle fruit fly traps dispensed through cotton wick and replenished at 3 months interval proved most economical.

The IPM developed by Kerala Agricultural University was evaluated visa-vis farmers practice of spraying malathion (0.1%) at monthly intervals under the unique homestead farming systems of Kerala. Analysis of infested fruits under different treatments revealed that the percentage infestation was significantly reduced during a two year study (2007-08) with methyl eugenol trap (1.13 and 1.34 % respectively) which was at par with the chemical control (Reji Rani *et al*., 2012).

Suk Ling Wee and Todd Shelly (2013) conducted an experiment in Hawaii and reported that traps baited with a solid formulation (termed a wafer) that contains both raspberry ketone and methyl eugenol plus dichlorvos, an insecticide captured as many or more *B. dorsalis* (Hendel) and *B. cucurbitae* (Coquillett) males as compared to traps baited with the standard liquid lures but in contrast traps baited with the wafer captured significantly fewer males than traps baited with liquid lures in Malaysia

To overcome the impact of *B. invadens*, in Mozambique, the use of integrated fruit fly management strategies for fruit fly population suppression has been applied by farmers, combining GF-120, bait spray, HymLure (food attractants combined with Malathion insecticide), male annihilation and orchard sanitation. Adult *B. invadens* population size was monitored on monthly basis using methyl eugenol baited traps. During the 2012-13 season, the mean population density of 0.4 flies per trap per day was much lower compared to the 8.5 flies captured in the control farms (with no IPM strategies application) corresponding to 95.5% population reduction on the IPM treated farms (Majacunene *et al*., 2014).

As per the studies made by Nagaraj *et al*. (2014c) on attraction of fruit fly to different quantities of methyl eugenol in mango orchard during 2008- 09 at GKVK campus, Bangalore. The result showed that traps charged with 0.4 ml methyl eugenol attracted significantly more fruit flies with mean trap catches of 22.66 fruit flies / trap / week followed by the traps charged with 0.2 ml and 0.8 ml methyl eugenol. However the lowest number of trap catch was recorded in the trap charged with 1.0 ml methyl eugenol.

The efficacy of different coloured traps in capturing fruit flies in mango orchards at G.K.V.K campus, Bangalore were investigated during the first fortnight of May 2008. When the total fruit flies irrespective of species were considered, yellow traps attracted more number of fruit flies with the mean trap catches of 18.60 fruit flies/trap/week followed by transparent and green colour traps (8.40 and 7.00 fruit flies/trap/week) which was at par with orange colour traps (4.80 fruit flies/trap/week) (Nagaraj *et al*., 2014d).

"Lure and kill technique" was adopted by Bhowmik *et al*. (2015) to monitor the incidence and management through mass trapping of fruit fly (*Bactrocera dorsalis* H.) in Nadia district of West Bengal with methyl eugenol. Three types of traps (trap-1: cotton impregnated with methyl eugenol; trap-2: methyl eugenol added in water and trap-3: methyl eugenol mixed with banana fruit and sevin) were used in mango. Among these, trap-1 was found most effective in mango with 16.07 and 15.03 fruit fly catch/trap/day during 2011 and 2012, respectively.

Krishi Vigyan Kendra at Navsari conducted demonstration on use of Nauroji pheromone. In 1ha experimental area of mango it is recorded that 26.32 per cent less infestation, 34.50 per cent more yield per ha obtained as compared to areas without pheromone traps (Nayka *et al*., 2015).

A study was conducted by Singh *et al.*(2015) in which wooden blocks (80 × 20 × 18 mm) made up of plyboard and locally available exotic Meranti wood (*Shorea* sp.) impregnated with a mixture of ethanol, methyl eugenol and malathion (6:4:1) were evaluated in a mango orchard in low hills of Himachal Pradesh. Suspension traps containing 100 ml solution of methyl eugenol (0.1%) and malathion (0.05%) in plastic bottles were used for comparison. The plyboard blocks were found more effective than Meranti wood blocks in trapping the fruit flies significantly with higher average number of adults (397.3/trap/week) compared to Meranti woodblocks (194.2/trap/week) and suspension traps (43.6/trap/week), respectively. The peak activity was observed during 24 to 31 standard weeks

An experiment conducted for three years data on infested fruits of mango revealed that hanging of wooden block (5x5x1 cm) in plastic bottle soaked in alcohol: methyl eugenol: DDVP (6:4:1) @10 traps/ha (replacement of wooden block at 2 months interval) was significantly superior followed by hanging of Rakshak Dapoli trap @10 traps/ha with replacement of lure at 2 months interval. Maximum yield and highest Incremental Cost Benefit Ratio (ICBR) were also observed with alcohol: methyl eugenol + DDVP (Ray *et al*., 2016).

2.5.2 Entomophathogenic agents

Trials in three southern districts of Kerala carried out in farmer's fields in the year 2009 revealed that there was significant reduction in the level of *B. dorsalis* and *B. cucurbitae* infestation where IPM was followed. The application of entomophathogen *Beauveria bassiana* effectively supplemented the integrated fruit fly management in mango and snakegourd (Jiji *et al*., 2010).

2.5.3 Protein baits

The responses of oriental fruit flies, *Bactrocera dorsalis* Hendel, to the odors of different stages and types of fruit presented on potted trees in a field cage. Females were most attracted to odour of soft, ripe fruit. Odours of common guava were more attractive to females than papaya and star fruit and equally as attractive as strawberry guava, orange, and mango. In field tests, McPhail traps baited with mango, common guava, and orange captured equal numbers of females. Traps baited with mango were compared with 2 commercially available fruit fly traps. McPhail traps baited with mango captured more females than visual fruit-mimicking sticky traps (Ladd traps) and equal numbers of females as McPhail traps baited with protein odours. Results from this study indicate that host fruit volatiles could be used as lures for capturing oriental fruit flies in orchards (Cornelius *et al*., 2000).

Studies were made by Ravikumar and Viraktamath (2007a) on attracting female fruit flies to different protein food baits in farmers' commercial guava and mango orchards during 2005-06 near Dharwad. Food bait containing proteinex and 5.0% ammonium acetate attracted significantly more *Bactrocera correcta* (5.17 fruit flies/trap/week), *B. dorsalis* (9.42 fruit flies/trap/week) *and B. cucurbitae* (2.25 fruit flies/trap/week) in guava while in mango, fruit fly diet and mango pulp both combined with 5.0 % ammonium acetate were attractive to *B. dorsalis* (7.63 and 4.63 fruit flies/trap/week, respectively) and *B. cucurbitae* (3.00 and 4.25 fruit flies/trap/week, respectively).

Studies on evaluation of protein food baits in attracting fruit flies in mango orchard (cv. Mallika) during 2008-09 at GKVK campus, Bangalore were made by Nagaraja *et al*. (2014e). Among various protein baits, traps baited with casein + sugar + mango was the most superior food bait attracting significantly highest number of fruit flies with a mean trap catch of 31.66 fruit flies/trap/week.

2.5.4 Chemical control

The study made by Dale and Patel (2010) on the effectiveness of various insecticides against fruit flies of mango indicated that a spray of either diamethoate (0.03%) or deltamethrin (0.001%), 45 days after flowering followed by two more sprays at monthly interval were most effective.

Among the nine insecticides tested, malathion (0.1%) proved to be the most effective against fruit fly in cucumber under the field conditions which was at par with fenthion (0.1%). Fenitrothion (0.03%) and alfamethrin (0.005%) stood second in order in their effectiveness. The highest yield of cucumber fruits (8299 kg/ha) was recorded in the treatment of malathion (0.1%) while fenitrothion (0.03%) and alfamethrin (0.005%) gave 7648 and 7255 kg/ha yield, respectively (Kate *et al*., 2010)

Field experiments were conducted by Khursheed and Raj (2012) to evaluate seven insecticides and biopesticides against fruit flies *Bactrocera* spp. in cucumber and bitter gourd. Abamectin (0.0015%) was the most effective treatment in terms of reducing the fruit infestation as well as number of maggots in both the crops. Lambda-cyhalothrin (0.004%) was the next best treatment followed by azadirachtin (0.0045%) and carbaryl 50WP (0.20%). However, chlorpyriphos 20EC (0.05%) and malathion 50EC (0.05%) were found to be inferior resulting in comparatively less reduction in fruit infestation and number of maggots per infested fruit.

Field experiments on the effect of different insecticides against fruit fly, *Bactrocera cucurbitae* Coquillett infesting sponge gourd was carried out during consecutive two years 2014 and 2015 at Junagadh Agricultural University, Junagadh byBharadiya and Bhut (2017**)**. They reported that insecticides abamectin 0.0025 per cent and emamectin benzoate 0.002 per cent were most effective and economic and were statistically at par with each other. The significantly minimum fruit infestation of 19.35 per cent had an increased yield of 32.01 per cent with a net return of Rs.

22695/ha was recorded in the treatment of abamectin while in emamectin benzoate 20.62 per cent fruit infestation and 29.10 per cent increased yield and Rs. 20625/ha net return was recorded. However, the treatment of dichlorovos 0.07 per cent (22.65% fruit infestation with 26.32% increased yield and Rs. 18660/ha net return) was proved the next best insecticide.

2.5.5 Integrated Pest Management

Integrated pest management (IPM) package was tested for control fruit flies which included:(1) male annihilation using wood blocks soaked in insecticide (malathion 50 EC) andlure (methyl eugenol and terpinyl acetate),(2) protein hydrolysate bait applications (Success Appat at 1 litre/ha) and (3) sanitation (weeding and destroying of thecollected fallen fruits by the following practices: using black plastic bags, burying inholes, burning on the ground surface and incinerating with a barrel transformed into incinerator). Results showed a control as an inferred improvement in fruit fly infestation in the treated plot up to 83% compared to the untreated. When methyl eugenol was compared to the home-made baits of ground nutmeg and NET, a beauty cream, it was found that methyl eugenol was more significant in the control of fruit flies (Ndiaye *et al*., 2008).

Surveys conducted during 2007-09 by Verghese *et al*. (2016) showed that mean infestation of fruit fly was 48.3% on assorted cultivars of mango grown in Srinivasapura. Productivity enhancement was achieved to an extent of 45.8% in the 62.3ha of demonstration area. This clearly indicated that a fruit lost due to fruit fly, if saved, is a fruit gained. The impact of the IPM consisting of male annihilation using methyl eugenol traps (15-20 traps/ha), destroying fallen fruits and bait splashes with jaggery (10%) + dichlorvos 78 EC (toxicant 2ml/l of bait) on the base of the main trunk, approximately 30cm above the ground @ 50ml bait/tree was found to give a mean yield increase of 124.53 tonnes across the whole area of demonstration. This resulted in a productivity increase from 4.37 tonnes to 6.37 tonnes/ha, an increase of 2.0 tonnes of fruit/ha.

2.5.6 Phytohormone

An experiment was carried out by Damodaram *et al*. (2015) to study the effect of salicylic acid (SA) treatment of mango fruit (cv. Totapuri) on oviposition and larval development of *B. dorsalis.* The results indicated that SA treatment reduced oviposition, larval development and adult emergence of *B. dorsalis* and a role of SA in enhancing mango tolerance to the pest was suggested.

2.6. Economic impact of fruit fly infestation

Fruit flies are serious pests in Pakistan, causing losses, at the farm level, of an estimated US$ 200 million annually, with added losses to traders, retailers and exporters. Small farmers suffer in particular, being the main growers of the highly susceptible guava and being unable to afford protection measures (Stonehouse *et al.,* 1997).

The attack of fruit flies is conveniently assessed by visual inspection of fruit. The study by Stonehouse *et al*. (2004) assessed the accuracy in Pakistan by recording visual diagnoses of attack on individual fruit and waiting to see if these were ‘‘confirmed’’ by subsequent emergence of prepupal larvae. Diagnoses as ‘‘unattacked’’ were overwhelmingly ‘‘confirmed’’; diagnoses as ‘‘attacked’’, by oviposition punctures, were ‘‘confirmed’’ by larval emergence in 56% of cases in melons, 39% in guavas, 40% in jujubes and 27% in mangoes.

The IPM package comprising of the following: (1) weekly removal of fallen fruits, (2) 3-weekly inter-tree ploughing and raking and (3)three fortnightly cover sprays of insecticide which were taken up over 45 days before harvest from 1985 to 1996 (eleven years) showed infestation reductions attributable between 77% and 100% in different years. Benefit:cost returns were dependent on the level of pest pressure and in years of low pressure the package may not recover its costs, necessitating a threshold approach (Verghese *et al*., 2004).

Ekesi *et al*. (2014) reported that mango yield was significantly higher in orchards receiving the bait sprays (12,487 kg/ha) compared with control orchards (3,606 kg/ha) in an experiment conducted in Kenya. Based on bait spray costs, yield data, and monetary gains, a cost:benefit ratio of 1:9.1 was realized, which is acceptable for growers.

The integrated pest management (IPM) package composed of male annihilation technique (MAT), protein bait spray, release of exotic parasitoid *Fopius* *arisanus* and the use of augmentorium was introduced to the farmers in Kenya. The difference-in-difference (DiD) method was used to assess the impact of the mango IPM on the magnitude of mango rejection and insecticide expenditure and net income. The study revealed that, on an average, mango IPM participants had approximately 54.5% reduction in the magnitude of mango rejection; spent 46.3% less on insecticides per acre and received approximately 22.4% more net income than the non-participants (Kibira *et al*., 2015).

2.7 Other crops

The field experiments were conducted during rabi season at Regional Research Station, Aruppukottai by Rajaram and Siddeswaran (2006) to study the effect of chemicals and plant products against the fruit borer and fruit fly complex in ber. The results revealed that the chemicals fenthion 0.1% recorded the lowest mean fruit damage of 26.46 % and is at par with endosulfan 0.07% with 26.67 % fruit damage and both are equally effective in controlling the fruit borer and fruit fly complex, whereas, the untreated control recorded the highest damage of 58.96 %. The azadirachtin 1% and *Ocimum sanctum* extract 1% are also effective only up to 10 days after spray.

Fruitfly, *Bactrocera tau* Walker, a devastating pest of tomato, lays eggs inside the fruits rendering them inaccessible to be targeted by insecticides. A study made by Sharma *et al.* (2011b) on effectiveness of drek seed kernels extract (DSKE) baits viz., bait I (0.25 % DSKE + diet), bait II (0.50 % DSKE + diet), bait III (1.0% DSKE + diet) was undertaken under laboratory conditions and compared with conventional poison baits, bait IV (0.05 % malathion + diet) and bait V (0.1 % malathion + diet) being practiced to manage this pest on tomato. The diet constituted of protinex: jaggary (1:1), yeast (5%) and ammonium acetate (0.1%). The bait III was most effective in reducing the egg laying (62.3eggs/10females) followed by bait II and bait I being with 74.1 and 90.3eggs/10females, respectively.

Field and laboratory experiments were conducted during 2010-11 at Fruit Research Station, Navsari Agricultural University, Gujarat to investigate the reaction of sapota varieties for their resistance/susceptibility to fruit fly, *Bactrocera dorsalis*. The genotypes, *viz.* PKM-1, PKM-2, DHS-1, DHS-2, Bhuripatti, Pilipatti and

Singapore were categorized as least susceptible to *B. dorsalis*. However, Zumakhiya, CO-2 and Kirthibarthi were found to be moderately susceptible. Likewise, Kalipatti, Cricket Ball, Paria Collection, Murabba and Mohangoote were recorded as highly susceptible to *B. dorsalis* (Nandre and Shukla 2013).

Eco-friendly insecticides along with some chemical insecticides were screened under three application schedules by Nath *et al.* (2014) against fruit fly infesting bitter gourd fruits and were compared with untreated control plot on the basis of fruit damage (%) during rainy seasons of the cropping years. The average of two rainy seasons data showed that the treatment schedule fenthion + fenthion + fenthion had least fruit damage (1.33%) by the fruit fly followed by achook + malathion bait spray + malathion (5.46%).

Presently noni (*Morinda citrifolia*) is being promoted for commercial cultivation targeting the supply of fruits to the industry. Although fruit flies are known to infest noni their seasonality and species spectrum have not been adequately understood. The study evaluates the seasonal catches of fruit flies in traps kept in noni ecosystems with two lure sources, namely, methyl eugenol (ME) and cue lure (CL). The catches were greater in ME traps than in CL trap. The major fruit fly species caught in ME traps in descending order were *Bactrocera dorsalis*, *B. correcta* and *B. zonata* while only *B. cucurbitae* was found in CL trap (Venkatachalam *et al*., 2014).

Ahmad and Begum (2017) conducted a trial to find out the efficacy of the lures, *viz*.methyl eugenol, raspberry essence and GF-120 in baited fruit fly traps in persimmon orchards in Kohat district, KPK Pakistan. The three treatments were T_1 (Methyl eugenol), T_2 (Raspberry essence) and T_3 (Gf-120). Results revealed highest population density of fruit flies/trap in T_1 (382), followed by T_3 (197.2) and T_2 (23.6).

MATERIALS AND METHODS

The present investigation entitled "Yield and Fruit Quality Loss as Affected by Fruit Fly in Mango (*Mangifera indica* L.)" was carried out to evaluate the seasonality of fruit fly incidence by monitoring the pest population using methyl eugenol traps, the quality of fruit fly affected fruits and the management of the pest using methyl eugenol traps and chemical pesticides. This chapter mainly deals with the details of procedures followed for conducting the experiment. The investigation was carried out at the Horticultural Research Station, Orissa University of Agriculture and Technology during the period from March, 2017 to May, 2018.

3.1 Location of experimental site

The Horticultural Research Station (HRS) of Orissa University of Agriculture and Technology is situated about 7 km away from the university and located at latitude of $20^{0}15'$ N and longitude of $85^{0}52'$ E. It is about 60 km away from the Bay of Bengal and has an altitude of 25.5 m above the mean sea level.

3.2 Soil and its characteristics

The composite soil sample (from 0-15 cm depth) was collected from the experimental plot and was analyzed physically and chemically. The data on the basis of physical analysis of soil are presented in Table 3.1.

Table 3.1. Soil characteristics of the experimental site

Sl.	Parameters	Status
1.	Texture	Sandy loam
2.	Sand (%)	77%
3.	Silt (%)	6%
4.	Clay (%)	17%
5.	Soil (pH)	4.71
6.	Bulk density	1.49
7.	Organic Carbon (g/Kg of soil	5.56
8.	Available Nitrogen (kg/ha)	346.0
9.	Available P_2O_5 (kg/ha)	43.0
10.	Available K_2O (kg/ha)	113.0

3.3 Meteorological observation

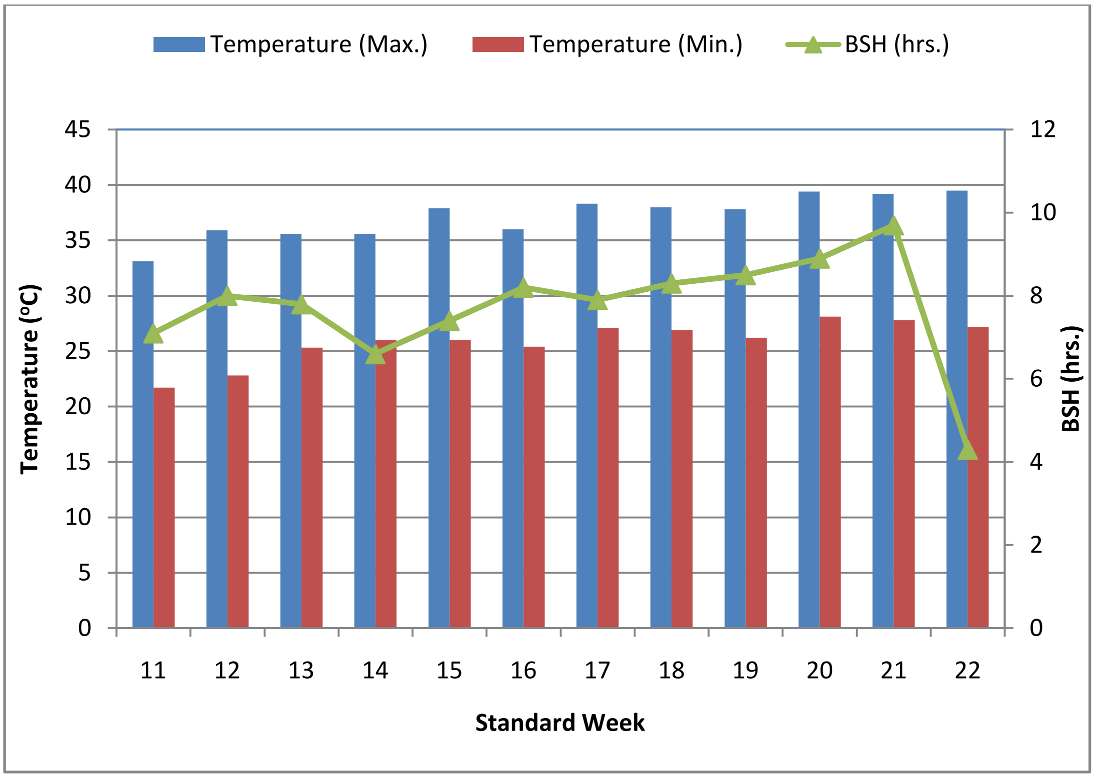
The weather data for the period from March to May during both 2017 and 2018 have been collected from the observatory of Orissa University of Agriculture and Technology at Bhubaneswar near the experimental site and have been presented in Table 3.2 and 3.3.

Table 3.2. Weather data of Horticultural Research Station, Bhubaneswar during 2017

Standard week	Temperature (^oC)		Relative humidity (%)		Total Rainfall (mm)	BSH (hrs)
	Max	Min	7hr	14hr		
11	33.1	21.7	92.0	40.0	0.0	7.1
12	35.9	22.8	89.0	36.0	0.0	8.0
13	35.6	25.3	88.0	45.0	0.0	7.8
14	35.6	26.0	87.0	46.0	0.0	6.6
15	37.9	26.0	86.0	44.0	0.0	7.4
16	36.0	25.4	88.0	56.0	29.2	8.2
17	38.3	27.1	88.0	51.0	0.0	7.9
18	38.0	26.9	83.0	47.0	0.0	8.3
19	37.8	26.2	85.0	46.0	27.5	8.5
20	39.4	28.1	83.0	46.0	0.0	8.9
21	39.2	27.8	80.0	44.0	0.0	9.7
22	39.5	27.2	79.0	46.0	18.6	4.3

Table 3.3. Weather data of Horticultural Research Station, Bhubaneswar during 2018

Standard week	Temperature (^oC)		Relative humidity (%)		Total Rainfall (mm)	BSH (hrs)
	Max	Min	7hr	14hr		
11	36.3	21.3	91.0	27.0	0.0	5.3
12	37.6	23.2	94.0	34.0	0.0	6.9
13	36.9	25.5	90.0	48.0	0.0	6.0
14	35.3	22.6	87.0	52.0	26.7	7.5
15	36.5	24.0	86.0	48.0	10.3	8.4
16	39.2	26.8	85.0	42.0	0.0	9.3
17	38.5	25.3	89.0	43.0	6.9	9.0
18	35.4	24.3	89.0	52.0	34.0	9.0
19	37.2	26.2	86.0	54.0	24.1	7.4
20	34.9	24.8	87.0	66.0	71.8	8.3
21	34.4	26.7	90.1	64.9	75.8	8.0



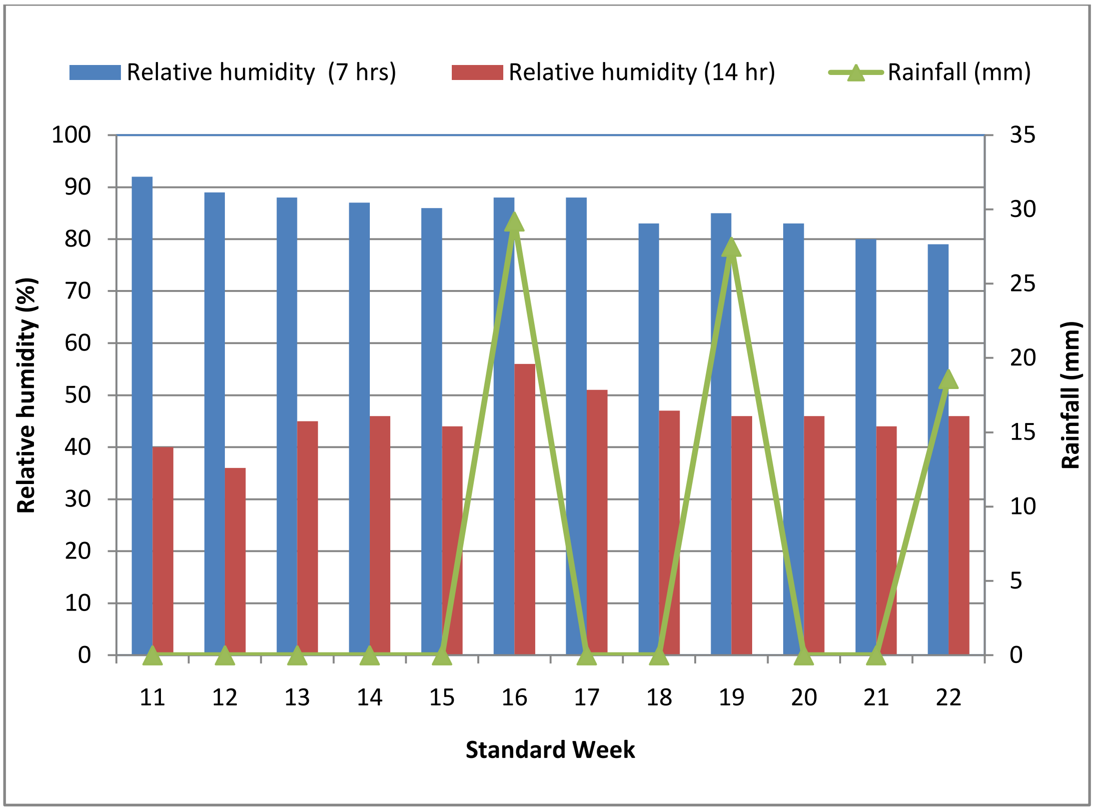
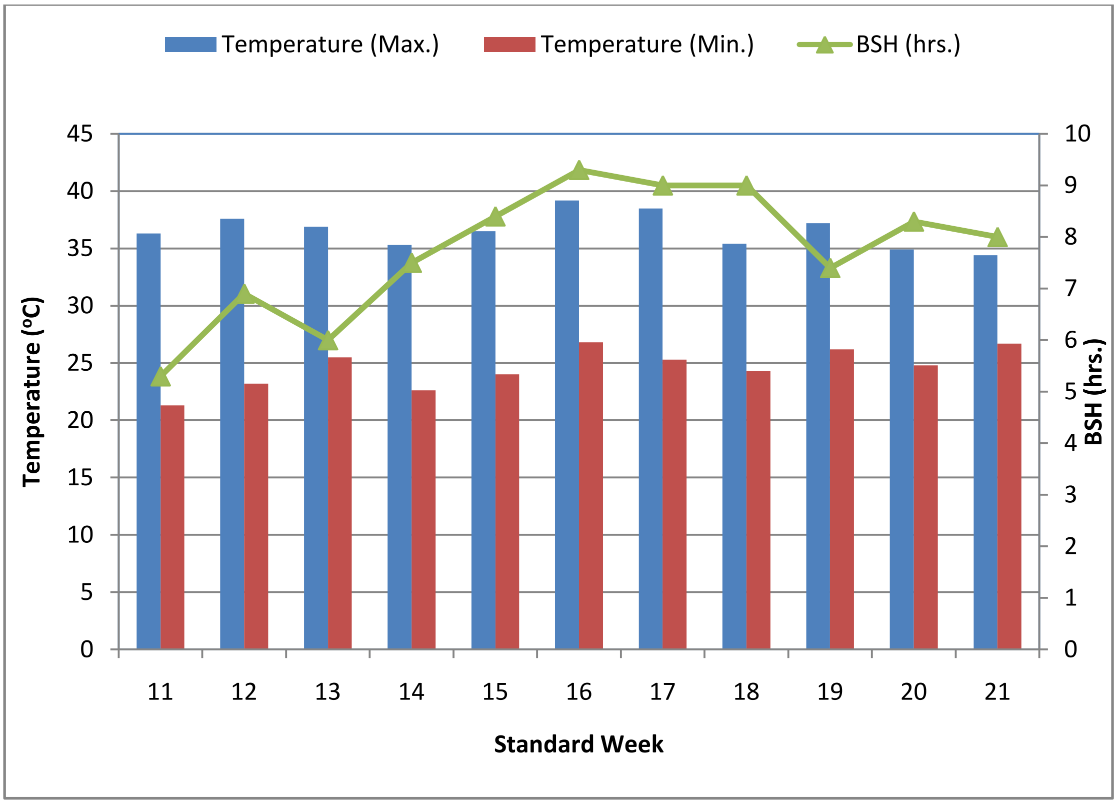


Fig. 3.1. Weather data of Horticultural Research Station, Bhubaneswar during 2017



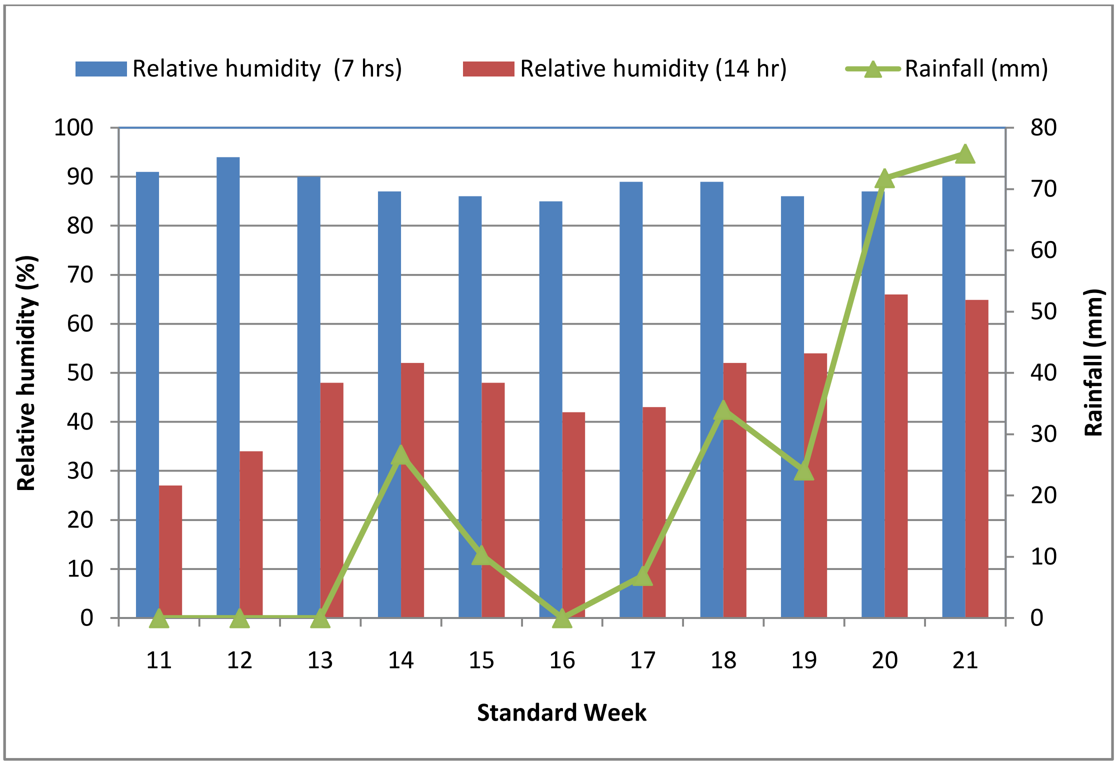


Fig. 3.2 Weather data of Horticultural Research Station, Bhubaneswar during 2018

3.4 Experimental details

The experiment consisted of two parts. In the first, starting March, 2017 seven major varieties in the Horticultural Research Station, namely, Dasheri, Langra, Totapuri, Suvarnarekha, Alphonso, Amrapali and Mallika were tested for their susceptibility to the incidence of mango fruit fly (*Bactrocera dorsalis* Hendel) through installation of methyl eugenol traps @ four traps for sixteen plants for each variety. The detailed procedure for installation of traps has been outlined under section 3.5.1. Since Amrapali constituted the majority of the varieties present in the research station as well as the state of Odisha and was also found to show a greater degree of susceptibility to the fruit fly, was selected as the test variety for the second part of the experiment during January-May, 2018.

3.4.1 Experimental design and layout

The experiment was laid out in Complete Randomized Block Design with seven treatments replicated thrice. The treatments were allocated at random to each replication using Fisher's random table. There were three Amrapali mango plants of six years age accommodated in each treatment and replication. A uniform spacing of 5m was given both between the rows and plants. The layout of the experiment has been given in Fig. 3.5.

3.4.2 Treatment details

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 under:

Table 3.4. Treatment details of the experiment

T_1	Methyl eugenol trap + Malathion 50 EC (2 ml/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)

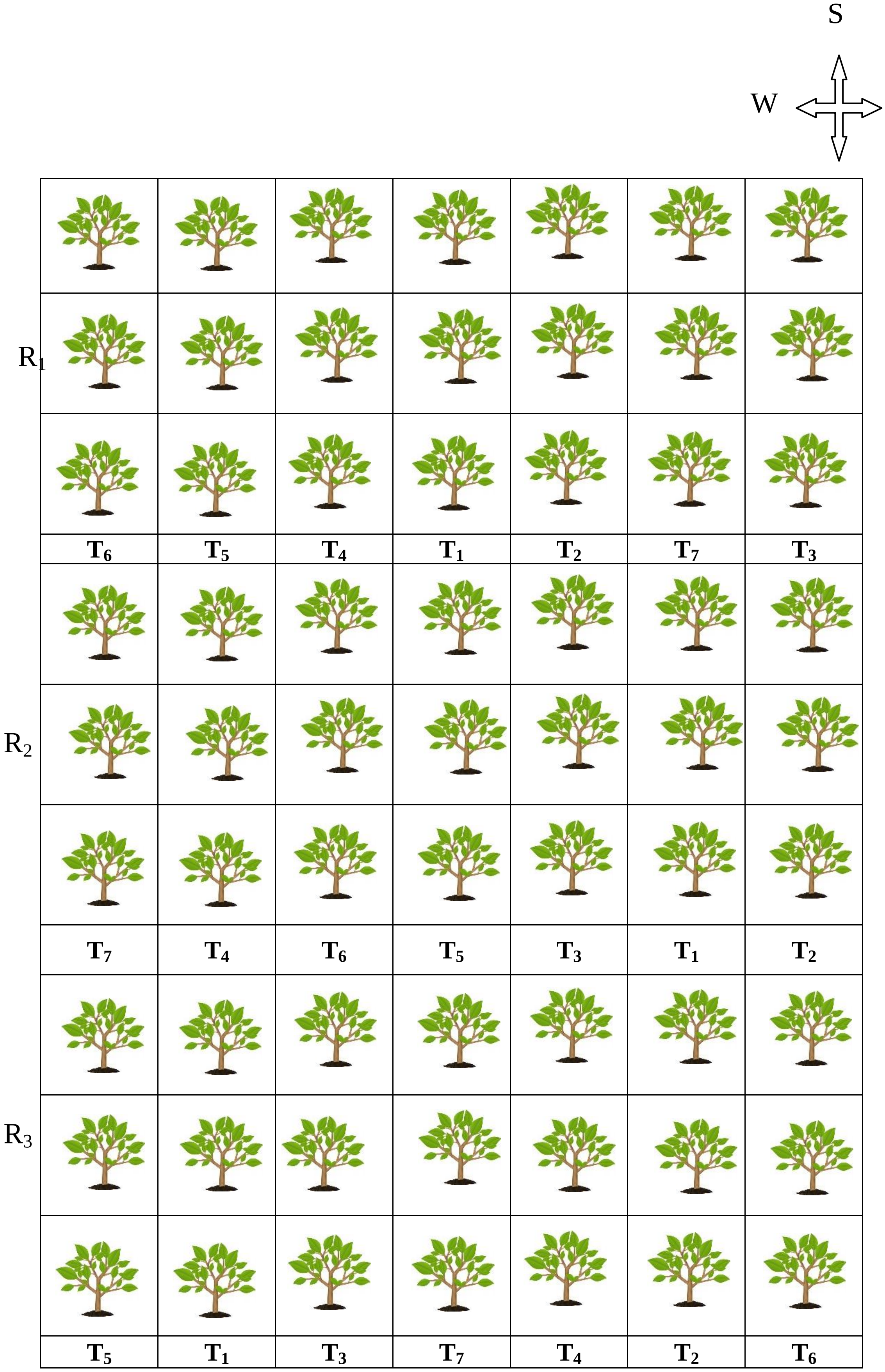


Fig. 3.3. Layout plan of the experimental plot

3.5 Monitoring of fruit fly incidence

3.5.1 Installation of traps for monitoring

The installation of methyl eugenol traps was done for monitoring the fruit fly population during 2017. The traps were installed from 11th standard week to harvest. The traps (Stonehouse *et al*., 2002) 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 centre by plastic thread to avoid wetting through rains. The jars were punctured with 2 cm holes at 4 places for the entry of flies. The traps were hung from the branches of good flower and fruit bearing plants at a height of 0.9 m (Madhura and Viraktamath, 2001). The traps were renewed at one month interval and maintained till harvest.

Based on the data recorded from seasonality studies, correlations were made between trap catches and weather parameters for every standard week. Weather parameters were correlated with the population of pest during the observation period and correlation coefficients were worked out.

3.6 Management of fruit flies

The management of fruit fly pest was done by installation of traps where the pests were trap in methyl eugenol fruit fly trap. Apart from this chemical management by spraying various insecticides was done as per the treatment of the experiment.

3.6.1 Management through methyl eugenol traps

The installation of methyl eugenol traps was done for management of fruit fly population. Installation of traps was started from 18th standard week till harvest. 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.

3.6.2 Management through insecticidal sprays

3.6.2.1Chemicals used in the experiment

For the management of fruit fly pest, traps using methyl eugenol and the lure as attractant and malathion as the insecticides were installed. The traps were maintained till the harvest of the fruits. During the later phase of fruit development when the fruits become susceptible to fruit fly attack different insecticides (both chemicals and botanical) (Table 3.5) were used. The doses of the insecticides as mentioned against them have been used for application as foliar sprays on the canopy of the plants @ 1.5 l of spray solution per plant.

Table 3.5. List of insecticides used in the experiment

Sl.	Name of the chemical	Concentration (a.i.)	Trade Name	Dose
1.	Malathion	50 EC	Malathion	2ml/l
2.	Cartap Hydrochloride	50 SP	Caldan	1g/l
3.	Deltamethrin	2.8 EC	Decis	1ml/l
4.	Fipronil	5 SC	Agadi	1.5ml/l
5.	Azadirachtin	0.03 %	Multiplex	2ml/l

3.6.2.2 Chemical solution preparation for spraying

The insecticides taken for the experiment were prepared as per the required doses, the details of which are discussed as under:

Malathion

Thirty mililitre of malathion (50 EC) was measured accurately by using measuring cap and mixed thoroughly by stirring with about a litre of water in a container. This insecticidal solution was transferred to the knapsack sprayer (fifteen litre capacity) and the volume was made up to the mark. It was stirred thoroughly in order to mix up the insecticidal solution with water. The thoroughly mixed solution was then taken for spraying to all the plants in the treatment.

Cartap Hydrochloride

Fifteen grams of cartap hydrochloride (50 SP) was weighed accurately and mixed in water thoroughly by stirring in a container. It was then transferred to a 15 litre knap sack sprayer and the volume was made up with addition of water. The thoroughly mixed solution was used for spraying all the plants in the treatment.

Fig. 3.4. Mango cv. Amrapali at flowering stage

Fig. 3.5. Observation being recorded on fruit drop

Deltamethrin

Fifteen militre of deltamethrin (2.8 EC) was measured accurately by using measuring cap and mixed thoroughly by stirring with about a litre of water in a container. This insecticidal solution was transferred to the knapsack sprayer (fifteen litre capacity) and the volume was made up to the mark. It was stirred thoroughly in order to mix up the insecticidal solution with water. The thoroughly mixed solution was then taken for spraying to all the plants in the treatment.

Fipronil

Twenty two and a half mililitre of fipronil (5 SC) was measured accurately by using measuring cap and mixed in water thoroughly by stirring in a container. The insecticidal solution was then transferred to a 15 litre knap sack sprayer and the volume was made up with addition of water. The thoroughly mixed solution was used for spraying all the plants in the treatment.

Azadirachtin

The insecticidal solution was prepared by measuring thirty mililitre of azadirachtin (0.03 %) by using measuring cap and mixed in water thoroughly by stirring in a container. It was then transferred to a 15 litre knap sack sprayer and the volume was made up with addition of water. The thoroughly mixed solution was used for spraying all the plants in the treatment.

Spraying for all the treatments was done to the plants through foliar application in the morning hours by a foot sprayer mixed with a neutral pH wetting agent@ 0.5 ml per litre of water. Two foliar sprays at fortnightly interval were taken up for all the plants in each replication and treatment. The spray solution was directed at the fruits instead of the whole tree canopy. All the insecticidal sprays were stopped a fortnight prior to harvest of the fruits. The application of the insecticides was stopped 10 days before harvesting.

3.7 Observation recorded

The followings are the observation recorded on various parameters during the whole period of the experiment.

3.7.1 Seasonality of fruit fly incidence

The seasonal incidence of mango fruit fly based on their population was monitored at weekly interval by trapping them using methyl eugenol fruit fly traps from 11th standard week (SW) till the harvest of the fruits during 2017.The numbers of flies trapped in each trap were collected and their count was made. The average of all the traps was made to find out the seasonal incidence of the fruit fly in mango. Based on the data obtained from seasonal incidence the correlations studies were made between the trap catch and weather parameters.

3.7.2 Extent of damage by the pest

The extent of damage caused to the fruits was assessed by the number of maggots emerging from the affected fruit samples in different varieties. For this twenty fully mature, ripened and fruit fly infested fruits were collected at random from each variety and placed inside closed polyethylene bags. The mean maggot number was calculated which indicated the extent of damage caused by the fruit flies. This parameter was used to find out the extent of damage by fruit fly in different varieties during 2017.

3.7.3 Trap catch of fruit fly in sprayed plot

The effect of insecticides on trap catch was evaluated by counting the mean trap catch from 11th SW till harvest in the sprayed plot.

3.7.4 Number and weight of affected fruits

The total fruits from dropped due to fruit fly incidence were recorded daily for each treatment and replication, both in number and weight (kg) from the date of installation of methyl eugenol traps for fruit fly management till harvest. The fruits affected by fruit flies were confirmed by the presence of fruit fly maggots in the fruits.

3.7.5 Number and weight of healthy fruits

Fruits Yield of healthy mature fruits from all the three selected plants was recorded in kilogram during harvest for each treatment. Both the number of fruits and the mean yield per plant was calculated.

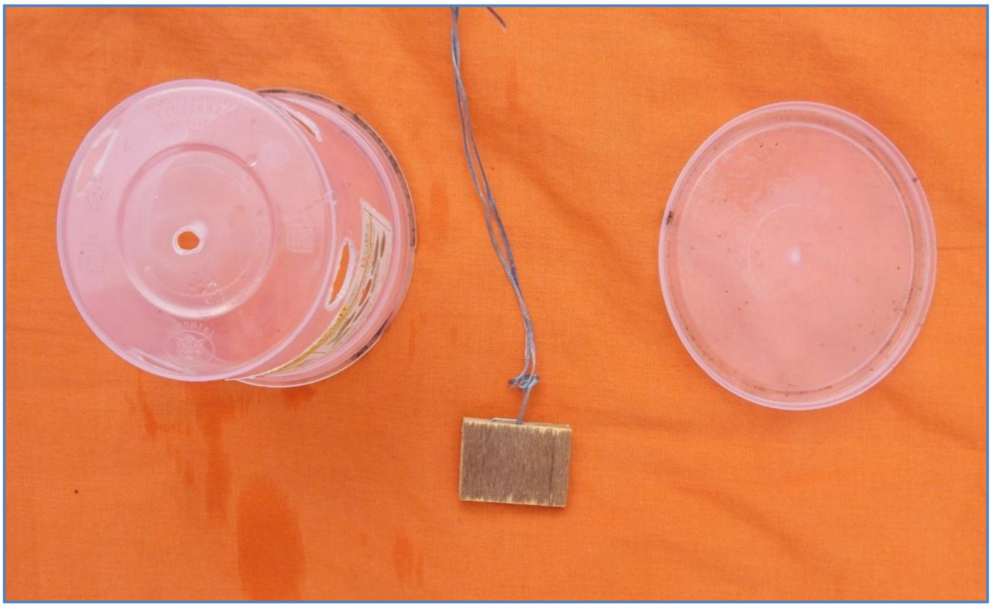


Fig. 3.6. Components of Methyl eugenol trap

Fig. 3.7. Methyl eugenol trap installed in mango plant

3.7.6 Percentage of affected fruits

The per cent of affected fruits by number with respect to total number of fruits harvested was worked out by the following formula:

$$\% \text{ of affected fruits (No.)} = \frac{\text{Number of affected fruits}}{\text{Number of affected fruits + Number of healthy fruit}} \times 100$$

In a similar way the per cent of affected fruits by weight with respect to total weight of fruits harvested was worked out by the following formula:

$$\% \text{ of affected fruits (weight)} = \frac{\text{Weight of affected fruits}}{\text{Weight of affected fruits + Weight of healthy fruits}} \times 100$$

The data were subjected to statistical analysis after transformation.

3.7.7 Extent of fruit fly infestation in mango cv. Amrapali

The extent of damage caused to the fruits was assessed by the number of maggots emerging from the affected fruit samples in different treatments. For this twenty fully mature, ripened and fruit fly infested fruits were collected at random from each treatment and placed inside closed polyethylene bags. The mean maggot number was calculated which indicated the extent of infestation caused by the fruit flies.

The extent of damage caused to the fruits was also assessed by the number of maggots recorded in the pulp of affected fruits at different stages of fruit development and maturity i.e. 4 WBH (week before harvest), 2 WBH and at harvest stage. This was used to find out a correlation between the quality parameters of fruits and the extent of damage caused by the fruit flies in mango cv. Amrapali.

3.7.8 Analysis of physicochemical parameters

The quality parameters like total soluble solids (TSS), reducing sugars, non reducing sugars, total sugars, titratable acidity, fruit firmness and peel thickness were estimated at different maturity stages by using the following methods.

A comparison of biochemical parameters between the fruit fly infested and healthy fruits was made. For this the fruits were allowed to ripen and the biochemical parameters estimated.

3.7.8.1 Estimation of total soluble solids (TSS)

The total soluble solids (^{0}brix) of the fruit samples were determined using Hand Refractometer. Five affected fruits of each treatment were used for the assay. The juice from each affected fruit was squeezed out and bulked together. Representative samples (about three drops) were taken and placed on the window of an absolute dry refractometer prism and read at 20 °C. The same procedure was followed for the healthy ripe fruits and data obtained were recorded accordingly.

3.7.8.2 Estimation of titratable acidity

The total acidity of a fruit could be determined by titrating a known amount of aqueous juice extract against an alkali solution of known normality. It is expressed as equi-volume of any organic acid e. g. citric acid, mallic acid etc.

Procedure:

20g of mango pulp was taken in a mortal and pestel. It was macerated well with addition of about 80ml water. After the pulp was well dissolved in water it was filtrated. The volume was made to 100ml with addition of water if required. Take 10ml of this aliquot in a conical flask. Add 1-2 drops of phenolphthalein indicator. It was then titrated against 0.1N solution of NaOH taken in the burette till a light pink colour appeared as the end point. Titration was continued till three concurrent readings were obtained. The titre value was recorded and the acidity of the sample was calculated as per the formula given below.

% Total acidity =

$$\frac{\text{Titre value (ml)} \times \text{Normality of NaOH(N)xVolume make up (ml) x equivalent wt. of critic acid x 100}}{\text{Weight of sample (g)} \times \text{Volume of aliquot (ml)} \times 1000}$$

3.7.8.3 Estimation of total sugar

The total sugar was determined by taking 10 ml of fruit juice extract in a 250 conical flask. Five ml of 1 N HCl was added to it followed by addition of 30 ml of distilled water. Then the content was heated for 4 to 5 minutes and then cooled (for inversion) in the water bath. The content was then transferred to a 250 cc conical flask and 2 to 3 drops of Phenolphthalein indicator was added to it. Then it was titrated against 1N NaOH solution taken in a burette. The appearance of light pink colour

Fig. 3.8. Fruit flies trapped in Methyl eugenol trap

Fig. 3.9 Adult fruit fly

indicated the end point. At this stage, the non-reducing sugar present in the fruit was converted to reducing state. The whole content is transferred to 100 cc volumetric flask and the volume was made up to the mark then it was transferred to a burette.

For estimation of total sugar 5 ml each of Fehling's solution A and Fehling's solution B solution were taken in a 250 ml conical flask followed by addition of 40 ml of distilled water and then heated over a flame. When the first bubble appeared it was titrated against the sample. Flask was put over a gas burner for heating. When first bubbles came out 2 to 3 drops of methylene blue indicator was added. Then it was titrated against sample in the burette till the end point came to brick red colour.

$$\text{Total sugar (\%)} = \frac{0.05 \times 100 \times 100}{\text{Titrate value} \times \text{Volume of sample}}$$

3.7.8.4 Reducing sugar

Fruits and vegetables contain reducing and non-reducing sugars in varying amount. Reducing and non-reducing sugars are important forms of carbohydrates. Glucose, fructose, mannose, galactose are reducing sugars whereas sucrose, lactose, and maltose are non-reducing sugars. Sugars having non reducing property are called as non reducing sugars (mainly sucrose).

The reducing sugars when heated with an alkaline cupric hydroxide present in Fehling's solution reduce the copper from the cupric to cuprous state and thus cuprous oxide is formed as precipitate (brick red colour). Formation of the coloured precipitate indicates the presence of reducing sugars in the solution.

Procedure

Juice was extracted from affected mango fruits. Ten ml of filtrate juice was taken in a 100 cc volumetric flask and the volume was made up to the mark by adding required amount of distilled water. The entire content is then transferred to a 100cc burette. In a 250 ml capacity conical flask 5 ml each of Fehling’s solution ‘A’ and ‘B’ were taken followed by addition of 40 ml distilled water and mixed thoroughly. The flask was put over a gas burner for heating. When first bubbles appeared 2 to 3 drops of methylene blue indicator was added. Then it was titrated against sample in the burette till the end point came to brick red colour.

$$\text{Reducing sugar (\%)} = \frac{0.05 \times 100 \times 100}{\text{Titrate value} \times \text{Volume of sample}}$$

3.7.8.5Non-reducing sugar

The content of non reducing sugar is to be converted to reducing sugar. The original reducing sugar and converted reducing sugar from non reducing fraction will give total sugar content in the sample. Non reducing sugar in the sample reduce copper from cupric state (cupric hydroxide) present in Fehling’s solution to cuprous state (cuprous oxide) when heated in presence of an alkali.

Procedure

The amount of non reducing sugar was worked out by taking the difference between total sugar and reducing sugar.

Percentage of non reducing sugar = (% of total sugar- % of Reducing sugar) x 0.95

3.7.8.6 Fruit Firmness

Firmness of the fruit in different stages of fruit development was determined using a Bosch penetrometer (model FT 327). This parameter was taken at the equatorial circumference of the fruits. The firmness was determined by the force (kg cm^{-2}) necessary for a 2 mm probe to puncture the fruit peel at four different points and taking average of the values (external firmness). A mean of ten different fruits were used as the sample mean.

3.7.8.7 Peel thickness

The peel thickness was measured randomly at five different positions in each fruit using a Vernier Caliper. A mean of ten different fruits were used as the sample mean for the peel thickness.

3.8 Economics

The incidence of fruit fly in mango may vary over years depending upon pest inoculums, climatic factors and many other situations resulting in the variable profitability of the crop. The economics of the mango crop with a relation to the different treatments was worked out taking into account the gross return, the variable cost of cultivation, the total cost of cultivation, net profit and the cost: benefit ratio per

Fig. 3.10. Fruit fly infested fruits of mango cv. Amrapali

Fig. 3.11. Fruit fly maggots in pulp of mango cv. Amrapali

hectare. The cost of cultivation was calculated on the basis of the prevailing local market rates of inputs while the gross return on the yield and sale price at the farm gate. The benefit: cost ratio is given by the following formula

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

3.9 Statistical analysis

Correlation coefficients were calculated by using SPSS version 11. An alpha level of 0.05 was used.

Analysis of variance and test of significance

The analysis of variance for each character was carried out with the mean values of each treatment under each replication. The total variance was positioned in components such as replication, treatment and error. The variance was tested at 5% level of significance. Standard Error of Mean and Critical Difference (0.05) were calculated for comparing the mean values as per Panse and Sukhatame (1954). The standard errors of mean and critical difference were calculated by using following formulae.

$$\text{SE (m)} \pm = \sqrt{\frac{EMS}{r}}$$

Where SE (m) = standard error of mean.

EMS = error mean sum of square

r = Number of replication

CD (0.05) = $\sqrt{2}$ x SE (m) x t value at error d.f. at 5 %.

RESULTS

The results recorded from the current experiment have been presented in this chapter under different sections and are supported by tabular data, diagrams, graphs and photographs at appropriate places. The data obtained from the experiment have been presented after statistical analysis as their means along with CD values for comparison of treatments.

4.1 Monitoring of fruit fly incidence

The incidence of fruit fly captured with Methyl Eugenol (ME) traps were from the 11th Standard Week (SW) when the fruits were around marble size to the 22nd SW within which all the fruits were harvested during the year 2017. The data on the fruit catch per SW indicated that initially there was little increases (upto 13th SW in Totapuri, Suvarnarekha, Alphonso and Mallika) and (upto 15th SW in Dashehari, Langra and Amrapali) (Table 4.1 and Fig. 4.1). A gradual increase in the population of fruit fly was observed from the 15th SW till the harvest of the crop in most of the varieties after which it declines. There was highest incidence of fruit fly in Suvarnarekha (70.25 mean trap catch/week) and Amrapali (65.75) during 19th SW and Dasheri (11.50), Langra (21.25), Alphonso (58.25) and Mallika (73.25) during 20th SW and Totapuri (104.25) during 21st SW. The range of fruit fly incidence as observed in the trap catch varied from a minimum of 1.75 in Dashehari in the 11th SW to a maximum of 104.25 in Totapuri during 21st SW. The mean trap catch was found to be 6.69 in Dashehari, 11.65 in Langra, 37.31 in Amrapali, 39.06 in Alphonso, 41.88 in Mallika, 42.00 in Suvarnarekha and 51.43 in Totapuri. Similarly the mean trap catch ranges from a minimum of 10.5 in the 11th SW to a maximum of 55.43 in 20th SW during the fruiting season in 2017.

4.2 Correlation of fruit fly incidence with weather parameters

Correlation analysis (Table 4.2) showed that there was a high significant and positive correlation between trap catch of fruit fly in Dashehari variety of mango with maximum temperature (r = 0.837) and minimum temperature (r = 0.811) while a high significant negative correlation was observed between the trap catch in Dashehari variety of mango with morning relative humidity (r = -0.729). Total rainfall and afternoon relative humidity had positive but non-significant effect on trap catch.

Table 4.1. Incidence of fruit fly in different mango varieties during 2017

Period	Std. week / Variety	Mean trap catch/week								
		Dashehari	Langra	Totapuri	Suvarnarekha	Alphonso	Amrapali	Mallika	Range	Mean±SD
March 12-18	11	1.75	3.25	11.75	17.00	17.00	10.25	12.50	1.75-17.00	10.50±6.04
19-25	12	2.25	4.25	17.75	19.50	17.75	12.75	18.50	2.25-19.50	13.25±7.18
26-01	13	2.50	3.00	21.00	24.00	17.00	17.00	23.75	2.50-23.75	15.46±9.13
April 02-08	14	3.25	6.75	22.50	30.50	26.25	22.75	27.00	3.25-27.00	19.86±10.55
09-15	15	4.75	9.25	25.50	31.00	29.75	27.25	30.50	4.75-30.50	22.57±10.89
16-22	16	7.00	13.50	35.70	36.50	40.75	38.00	34.50	7.00-40.75	29.42±13.38
23-29	17	8.50	14.50	56.50	40.00	47.50	43.50	41.00	8.50-56.50	35.93±17.65
May 30-06	18	8.75	17.25	65.50	54.50	55.25	54.75	51.00	8.75-65.50	43.86±21.69
07-13	19	11.00	17.50	80.00	70.25	57.75	65.75	60.75	11.00- 80.00	51.86±26.73
14-20	20	11.50	21.25	93.50	65.75	58.25	64.50	73.25	11.50-93.50	55.43±29.05
21-27	21	10.50	20.75	104.25	61.50	51.50	48.75	68.50	10.50-104.25	52.25±31.10
28-03	22	8.50	8.50	83.25	53.50	50.00	42.50	61.25	8.50-83.25	43.93±27.35
	Mean	6.69	11.65	51.43	42.00	39.06	37.31	41.88	6.69-51.43	32.86

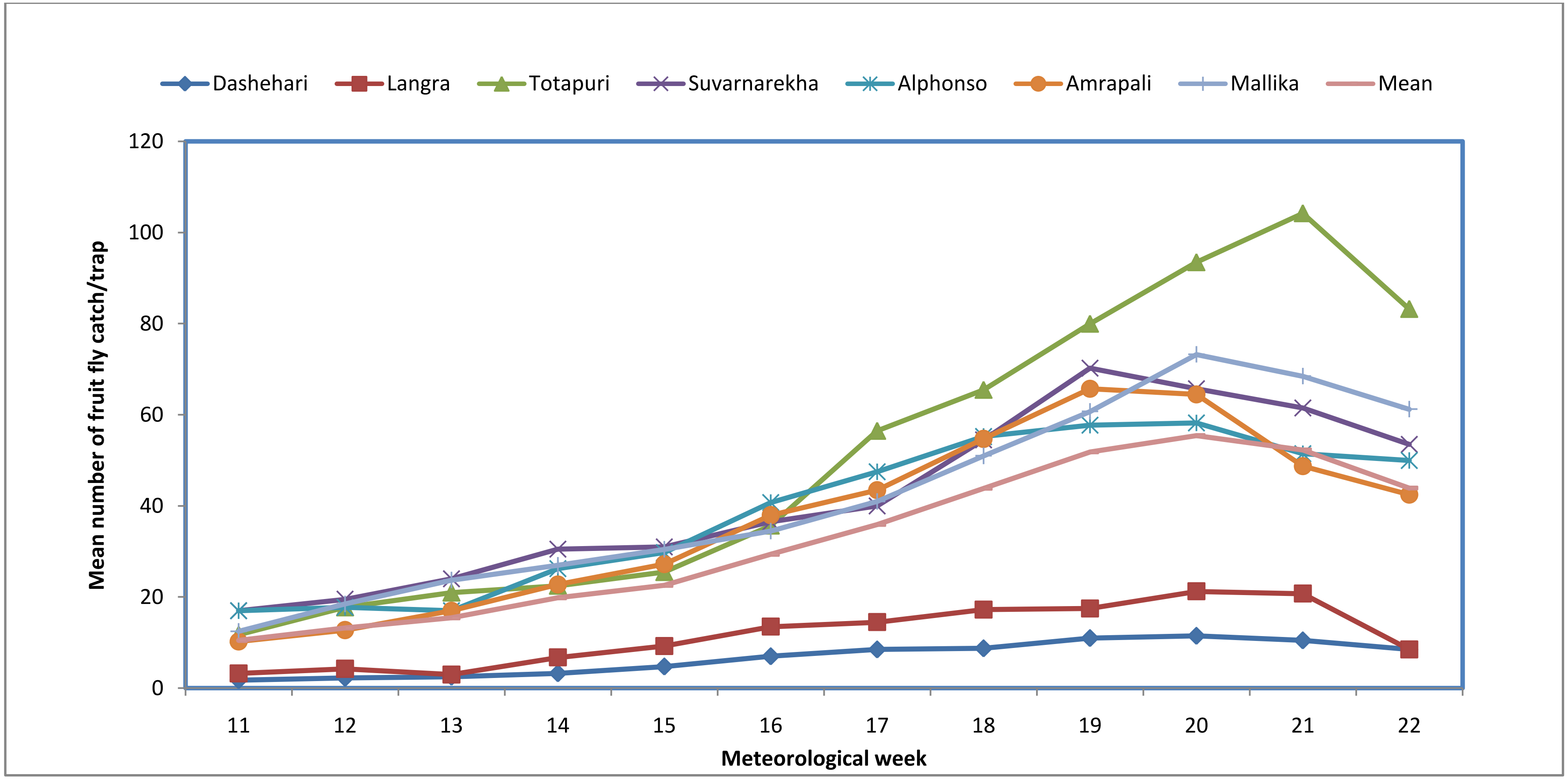


Fig. 4.1 Incidence of fruit fly in different mango varieties during 2017

Table 4.2. Correlation of fruit fly incidence in different mango varieties with weather parameters (2017)

Variety	Max. Temp. (^0C)	Min. Temp. (^0C)	Morning RH (%)	Afternoon RH (%)	Rainfall (mm)
Dasheri	0.837**	0.811**	-0.729**	0.450	0.348
Langra	0.732**	0.757**	-0.603*	0.434	0.188
Totapuri	0.857**	0.795**	-0.855**	0.241	0.213
Suvarnarekha	0.806**	0.790**	-0.789**	0.321	0.349
Alphonso	0.820**	0.805**	-0.732**	0.486	0.361
Amrapali	0.779**	0.786**	-0.670*	0.457	0.365
Mallika	0.881**	0.844**	-0.867**	0.294	0.249

** = significant at 0.01, * = significant at 0.05

In case of Langra variety there was high significant and positive correlation between trap catch with maximum temperature (r = 0.732) and minimum temperature (r = 0.757) while a significant and negative correlation with morning relative humidity (r = -603) was recorded. Non-significant result was observed positive both for afternoon relative humidity and total rainfall.

Fruit fly trap catch in Totapuri variety showed a high significant and positive correlation with maximum and minimum temperature (r = 0.857 and 0.795, respectively). A high significant but negative correlation was also observed with morning relative humidity (r = -0.855). With respect to afternoon relative humidity and rainfall a non-significant and positive correlation was observed.

In Suvarnarekha, the trap catch had a significant and positive correlation with maximum temperature and minimum temperature (r = 0.806 and 0.790, respectively). It also showed high significant negative correlation with morning relative humidity (r = -0.789). Total rainfall and afternoon relative humidity had a positive and non-significant correlation with trap catches.

The trap catch in mango cv. Alphonso had a positive and high significant correlation with maximum and minimum temperature (r = 0.820 and 0.805, respectively) while it showed negative and high significant correlation with morning relative humidity (r = -0.732). Rainfall and afternoon relative humidity showed non-significant and positive correlation.

The maximum and minimum temperature had a positive and high significant correlation (r = 0.779 and 0.786, respectively) with the trap catches in mango cv. Amrapali whereas the morning relative humidity was negatively correlated (r = -0.670) but significant. Rainfall and afternoon relative humidity did not show any significant correlation.

The correlation studies between incidence of fruit fly and weather parameters in variety Mallika showed a positive and high significant correlation with maximum temperature (r = 0.881)and minimum temperature (r = 0.884) while it was negatively correlated with morning relative humidity (r = -0.867). It also recorded a positive but non-significant correlation with afternoon relative humidity and rainfall.

4.3 Extent of infestation in different varieties of mango

The data presented in Table 4.3 indicates the extent of infestation by fruit fly as evidence from the infested fruits after harvest. The mean number of maggot emergence from the infested fruits range from a minimum of 1.13 in Dashehari to a maximum of 6.40 in Suvarnarekha. There was a significant difference in this character between the varieties. Suvarnarekha had a significant maximum fruit infestation by fruit fly and Dashehari exhibited a significantly minimum. Langra was at par with Dashehari in respect of this character.

4.4 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 4.4. The mean trap catch per week taken as an average over all the SW varied from a minimum of 23.33to a maximum of 50.33. The trap catch in the absence of any insecticides (T_6) resulted in a significantly maximum of 50.33 among all the treatments. T_3, i.e. methyl eugenol (ME) trap + spraying with deltamethrin resulted in a significant minimum value of 23.33 for the said character. There was a reduction of 53.46 percent in the mean trap catch of fruit fly over T_6. All the insecticides are found to exert a significant difference among themselves in respect of the trap catches of fruit fly per week.

4.5 Percentage of fruit fly infestation (No.)

The percentage of fruit fly infestation in variety Amrapali was calculated after the harvest of fruits. The Table 4.5 indicated the percentage of infested fruits by number. Treatment (T_3) (3.43 percent) resulted in significantly lowest percentage of infested fruits and the control treatment T_7 (11.85 per cent) the significantly maximum 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.

4.6 Yield and percentage of fruit fly infestation (weight)

The yield of fruits from different treatments ranged from a minimum of 11.68 kg plant^{-1} in T_7 to a maximum of 23.73 kg plant^{-1}in T_3.

Table 4.3. Extent of infestation in different varieties of mango

Treatment	Mean No. of maggot emergence/fruit
Dasheri	1.13 (1.05)
Langra	1.07 (1.03)
Totapuri	6.10 (2.47)
Suvarnarekha	6.40 (2.53)
Alphonso	4.53 (2.13)
Amrapali	3.20 (1.79)
Mallika	5.57 (2.36)
SEm (±)	0.072
C.D. (0.05)	0.22

(Figures in the parentheses are square root transformed values)

Table 4.4. 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)

Table 4.5. Percentage of fruit fly infestation in mango, cv. Amrapali (No.)

Treatments		No. of infested fruits/plant	No. of harvested fruits/plant	% Infestation
T_1	Methyl eugenol trap + Malathion 50 EC (2 ml/l)	7.67	122.33	5.92 (2.43)
T_2	Methyl eugenol trap + Cartap Hydrochloride 50 SP (1 g/l)	7.33	134.00	5.22 (2.28)
T_3	Methyl eugenol trap + Deltamethrin 2.8 EC(1 ml/l)	5.55	154.00	3.43 (1.85)
T_4	Methyl eugenol trap + Fipronil 5 SC (1.5 ml/l)	6.78	139.00	4.76 (2.16)
T_5	Methyl eugenol trap + Azadirachtin 300 ppm (2 ml/l)	8.11	116.22	6.43 (2.51)
T_6	Methyl eugenol trap only	8.67	102.78	7.79 (2.79)
T_7	Control	10.11	76.56	11.85 (3.44)
SE m(±)		-	7.96	0.15
C.D. (0.05)		-	24.52	0.45

(Figures in the parentheses are square root transformed values)

The percentage of fruit fly infestation was calculated after the harvest of fruits and recording the weight in kg/plant in Amrapali variety. The percent infestation by weight were calculated from the total weight of harvested and infested fruits in kg/plant and presented in Table 4.6.It is evident from the data that 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 maximum 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 4.6. Percentage of fruit fly infestation in mango, cv. Amrapali (Weight)

Treatment		Weight of infested fruits (kg/plant)	Weight of harvested fruits (kg/plant)	% Infestation
T_1	Methyl eugenol trap + Malathion 50 EC (2 ml/l)	0.49	18.81	2.55 (1.60)
T_2	Methyl eugenol trap + Cartap Hydrochloride 50 SP (1 g/l)	0.45	20.56	2.16 (1.46)
T_3	Methyl eugenol trap + Deltamethrin 2.8 EC(1 ml/l)	0.45	23.72	1.85 (1.36)
T_4	Methyl eugenol trap + Fipronil 5 SC (1.5 ml/l)	0.45	21.49	2.11 (1.44)
T_5	Methyl eugenol trap + Azadirachtin 300 ppm (2 ml/l)	0.68	18.00	3.63 (1.90)
T_6	Methyl eugenol trap only	0.91	15.72	5.53 (2.34)
T_7	Control	0.99	11.68	7.99 (2.82)
SE m(±)		-	1.24	0.10
C.D. (0.05)		-	3.83	0.31

(Figures in the parentheses are square root transformed values)

4.7 Extent of fruit fly infestation in mango cv. Amrapali

The Table 4.7 indicated the data regarding the extent of fruit infestation in mango cv. Amrapali by fruit flies. It was calculated by taking the mean number of maggots emerging from the fruits. 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_4in 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.

Table 4.7. 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)

4.8 Correlation between quality parameters and extent of infestation

The extent of infestation in fruits of cultivar Amrapali has been evaluated at harvest, two weeks before harvest (WBH) and 4WBH and presented in Table 4.8. The quality parameters, namely, TSS, total sugar, acidity, fruit firmness and peel thickness have been analysed and presented in Table 4.9. Correlation studies were carried out using the values in Table 4.8 and 4.9 and presented in Table 4.10.

Table 4.8. 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
2 WBH	3.0
At harvest	5.2

Table 4.9. Quality parameters of mango, cv. Amrapali fruits at different stages of development

Character	Stage of harvest	Value
TSS (^{0}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

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.

Table 4.10.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*

** = significant at 0.01, * = significant at 0.05

4.9 Biochemical parameters in fruit fly infested and non infested fruits

Both fruit fly infested and non infested fruit of mango cv. Amrapali were analysed for different biochemical parameters namely, TSS, reducing sugar, non reducing sugar, total sugar and acidity and the values are presented in Table 4.11. The data in the table 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.

Table 4.11. 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

4.10 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 4.12. The cost of cultivation, gross return and the net return have been calculated basing on the prevailing rates of inputs in the local market and the sell price of mangoes at the farm gate. The economic data showed that the differential cost of cultivation involving the costs of the traps and their installation, the insecticides and their application 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 range 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 range 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 resulted in Rs. 37680ha^{-1}. The B:C ratio was also reflected in a similar way with a value of 1.06 from T_7 and 2.11 from $T_{3.}$

Table 4.12. Economics of different treatments

Treatment	% Infestation	Yield (t ha^{-1})	% Increase in 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}, (Figures in the parentheses are square root transformed values)

DISCUSSION

The complete experimental findings of the present experiment entitled "Yield and Fruit Quality Loss as Affected by Fruit Fly in Mango (*Mangifera indica* L.)" are being discussed in this chapter with proper justification, critical comments and supporting evidences under the following broad groups.

5.1 Monitoring of fruit fly incidence

The results of captured of mango fruit fly adults in different varieties of mango recorded at 7 days interval during 2017 have been presented in Table 4.1 and Figure 4.1. During the year the mean trap catches increases gradually from 11^{th} SW and reached a peak in the 19^{th} SW in varieties Swarnarekha and Amrapali in the 20^{th} SW in varieties Dashehari, Langra, Alphonso, mallika and in the 21^{st} SW in Totapuri. This variation in peak period occurrence of fruit flies may be attributed to the differences in the maturity period of the test varieties. Kumar *et al*. (1997) and Sarada *et al*. (2001) have also observed similar peaks of fruit flies in mango in the period from April to June. Ravikumar (2005) and Ravikumar and Viraktamath (2007b) have also noticed the peak trap count of *Bactrocera* during the month of May.

5.2 Correlation of fruit fly incidence with weather parameters

Correlation studies between trap catches of fruit fly in different varieties of mango and weather parameters like temperature, relative humidity and rainfall have been made and presented in Table 4.2.The data showed that all the varieties viz. Dashehari, Langra, Totapuri, Suvarnarekha, Alphonso, Amrapali and Mallika have a positive and highly significant correlation with the maximum temperature and minimum temperature. Similar findings were made by Kannan and Rao (2006) who reported that incidence of fruit fly is significant and positively correlated with maximum and minimum temperature. Likewise, the findings of Stanley *et al*. (2015) also showed a positive correlation with maximum and minimum temperature.

With respect to morning relative humidity, all the mango varieties showed a negative and high significant correlation with the fruit fly populations which was also supported by the findings of Kannan and Rao (2006). In contradiction, Nagaraj *et al*.

(2014a) and Ranjitha and Viraktamath (2006) reported a highly significant and positive correlation of fruit fly incidence with morning relative humidity. The present correlation analysis result showed a non-significant but positive effect in case of afternoon relative humidity and rainfall with fly trapped in all the varieties.

5.3 Extent of infestation in different varieties of fruits

The level of infestation in all the mango varieties during the year 2017 was calculated by counting the number of maggots emerging from the infested fruits and the data were presented in Table 4.3. The results revealed that the variety Suvarnarekha recorded the maximum number of maggot emergence followed by Totapuri which means these varieties were more susceptible to fruit fly infestation as compared to other experimental varieties. However, the least number of maggots was recorded from the mango cv. Langra. Dashehari also recorded a lower extent of infestation after the variety Langra. The present finding endorse the report of Verghese *et al.* (2002) where the cv. Dashehari and Langra were categorized as the least infested with the cultivars Suvarnarekha and Totapuri as the most infested one in the field. The present results are also in line with Kalia and Srivastava (1992) who reported higher number of maggot emergence in Mallika in comparison to Amrapalli and Dashehari. In contrast, Singh *et al.* (2008) reported highest damage in mango cv. Mallika (56.6 per cent) followed by Totapuri (37.8 per cent) in fully ripened fruits. Similarly, Godse and Bhole (2002), Kumar *et al.* (2002) and Kumar *et al.* (1994) found that the variety Alphonso suffered the most significant damage due to fruit flies.

5.4 Effect of insecticides on the trap catch of fruit fly in mango, cv. Amrapali

The application of insecticides has definite effect on the number of fruit fly visiting the traps. In the Table 4.4 we find that 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 in azadirachtin, malathion, cartap hydrochloride, fipronil and deltamethrin with catches of 44.67, 36.33, 31.67, 27.67 and 23.33, respectively. The number of fruit fly catch per trap also coincided with that of per cent infestation of fruits by the insect where the values have been presented in Table 4.6. The application of deltamethrin resulting in the minimum infestation of fruits has also been reported by Singh (1997).

5.5 Yield and Percentage of fruit fly infestation (No. and weight)

The data regarding the per cent fruit infestation by fruit flies in terms of both number and weight were analyzed by taking into account the infested fruits and total marketable fruits (both in numbers and weight) and are presented in Table 4.5 and 4.6. 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. The present experimental finding showed that the treatment T_3 (ME trap + deltamethrin) recorded the lowest per cent fruit infestation and highest marketable yield followed by T_4 (ME trap + fipronil) while the treatment T_7 (control) and T_6 (ME traps only) recorded the highest fruit infestation level and the lowest yield in mango cv. Amrapali both in number and weight. The present result proved deltamethrin as the most efficient insecticide in controlling the population build up of fruit flies in the field level apart from the use of ME traps. These findings are in accordance with the results of Dale and Patel (2010) 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) also made a similar finding where they reported deltamethrin to be the most effective insecticide in managing fruit fly population in mango @ 0.0025 per cent. Synthetic pyrethroids (permethrin, cypermethrin, fenvalerate and deltamethrin) were superior to malathion in controlling fruit flies infesting bittergourd (Rabindranath and Pillai, 1986). Likewise Sood and Sharma (2004) reported significantly less fruit infestation by cucurbit fruit fly in treatments with pyrethroids (deltamethrin, cypermethrin and fenvalerate) in comparison to malathion.

5.6 Extent of fruit fly infestation in mango cv. Amrapali

The degree of infestation by the fruit flies can be assessed by both mean no. of maggots emerging from the fruit around the ripening time and the count of mean number of maggots in the pulp of the fruits after dissection. The number of maggots emerging from the fruit after harvest is presented in Table 4.7 which varied from 3.18 in the control to 2.50 in T_3. 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.

It is pertinent to say that these two insecticides (malathion and azadirachtin) are effective in recording significantly lower number of trap catch per week but that could not prevent the flies from infesting the fruits. The present finding is in agreement with Shukla *et al*. (1984) who tested seven insecticides against *Bactrocera* and reported deltamethrin 0.0025 per cent to be the most effective one in comparison to others.

The maximum trap catches (50.33) resulted in 7.79 per cent and 5.53 per cent infestation in number and weight basis respectively and such damage level were significantly lower than untreated control 11.85 per cent and 7.99 per cent in number and weight respectively. Moreover, used of only ME trap seemed to be economic and a better proposition as no pesticide was used.

5.7 Extent of infestation and biochemical parameters at different stages of fruit maturity

The extent of fruit infestation and biochemical constituents at different stages of fruit development and maturity were observed and presented in Table 4.8 and 4.9 which showed that TSS and total sugar increases with maturity while acidity, fruit firmness and peel thickness decreases. The result also showed that the incidence of fruit fly infestation increase in the later part of fruit development and towards 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). Rattanapun *et al.* (2009) 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.

5.7 Correlation between quality parameters and extent of infestation

The correlation studies between the fruit infestation percentage and quality parameters of mango cv. Amrapali were made by taking the values in Table 4.8 and 4.9 at different stages of fruit development and are presented in the Table 4.10. The present experimental result showed a positive and significant relation between the fruit TSS and total sugar with the fruit fly infestation. However, a negative and significant correlation was observed between total fruit acidity with fruit fly infestation and thus considered to impart resistance against the pest. Higher the TSS towards the ripening stage fruit flies are more attracted to the ripened and fully ripened fruits. This finding is in line with the results of Venkata Rami Reddy and Vasugi (2008) who reported a significantly positive and relation between TSS and fruit fly infestation and a significantly negative correlation with total acidity in guava. Arora *et al.* (2000) 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) and Rattanapun *et al*. (2009)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) 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) 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 puparia were lighter and smaller in size. Thus the present findings are in agreement with these observations.

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

The biochemical parameters of both the fruit fly infested and non infested fruits of mango variety Amrapali were analyzed and the data are presented in Table 4.11. The present finding revealed that the biochemical parameters like TSS, reducing sugar, non reducing sugar and total sugar were higher in fruits which are not infested by the pest. However, the fruit fly infested fruits showed higher level of total acidity in comparison to healthy fruits. The present results are in accordance with the findings of Akoto *et al.* (2011) 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).

5.9 Economic analysis

Different insecticides application including bio-insecticides have distinctly increase the yield of mango over the two checks T_6 (ME traps only) and T_7 (no trap and no insecticide application). The increases in yield in comparison to the checks were due to the differential efficacy of insecticides and the trap. All the treatments involved different cost arising out of the cost of trap and its installation, the cost of insecticides and their application. 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}). The benefit:cost ratio varied from a highest of 2.11 in deltamethrin application + trap (T_3) to a lowest of 1.43 in use of no trap and no insecticide (T_7). The treatments to follow deltamethrin were fipronil + ME trap (1.91), cartap hydrochloride + ME trap (1.82) and malathion + ME trap (1.67). Different workers have reported different net returns and B:C ratios depending on the different insecticides used and locations of study.

SUMMARY AND CONCLUSION

Mango is one of the important commercially grown tropical fruit crop of India and the world. Quarantine of mango fruits is regarded as one of the biggest bottleneck in the export of mango fruits. One of the important pests responsible for the low export from quarantine point of view is the mango fruit fly (*Bactrocera* spp). Apart from mango these flies also attacked other fruit crops like guava, citrus, bael, peach, sapota etc. It causes around 27 per cent of loss in the harvest of mango fruits in the country. The damage to the fruits is severe since they are attacked by both adults and maggots. Presence of fruit fly larvae causes change in the quality parameters such as TSS, total acidity, internal damage area etc.

Mango growers in the country often go for indiscriminate use of toxic pesticide for controlling the pest resulting in higher pesticide residues in the fruits and disturbed ecological balance. Alternate method available for the management of the pest includes ME traps and bait traps as they are effective and environment friendly. The present investigations entitled "Yield and Fruit Quality Loss as Affected by Fruit Fly in Mango(*Mangifera indica* L.) has been undertaken to find out the seasonality of fruit fly incidence and evaluate the efficacy of different insecticides in the management of fruit flies in mango.

The experiment has been carried out at the Horticultural Research station, Orissa University of Agriculture and Technology, Bhubaneswar during the fruiting seasons of mango in seven varieties during 2017. During this year, the mean trap catch of fruit flies per week for different varieties indicated that the peaks of fruit flies were observed in 19^{th} SW in Suvarnarekha and Amrapali, in the 20^{th} SW in Dashehari, Langra, Alphonso and Mallika and in the 21^{st} SW in Totapuri. The mean trap catch was found to be 6.69 in Dashehari, 11.65 in Langra, 37.31 in Amrapali, 39.06 in Alphonso, 41.88 in Mallika, 42.00 in Suvarnarekha and 51.43 in Totapuri.

Correlation between mean trap catch per week and weather parameters indicated significant positive values for maximum and minimum temperature and significantly negative values for morning relative humidity and no correlation with afternoon relative humidity and total rainfall. Suvarnarekha had a significant maximum fruit infestation to the tune of 6.40 maggots per fruit in comparison to Langra with a lowest value of 1.07 maggots per fruit.

Since Amrapali is a leading variety of Odisha and has a significant infestation by fruit flies, it was selected as the test variety for the management of the pest during 2018. For this, the experiment was conducted in Randomized Block Design with seven treatments replicated thrice. The treatments included five insecticides including bio-insecticide along with ME traps with two checks; a check with only trap and another without any trap or insecticide. Traps were installed during the year 2018 from 18^{th} SW and maintained till the harvest of the fruits.

The treatments containing only ME trap and no insecticide attacked maximum mean trap catch per week (50.33) and the treatment deltamethrin + ME trap the lowest (23.33). The control treatment (T_7) resulted in maximum infestation of 11.85 per cent by number and 7.99 per cent by weight whereas deltamethrin + ME trap had a minimum of 3.43 per cent by number and 1.85 per cent by weight followed by Fipronil application + ME trap with 3.43 per cent by number and 2.11 per cent by weight.

The extent of infestation of fruits as indicated by mean number of maggots emergence was significantly lowest in deltamethrin + ME trap (2.50) in comparison to a highest per fruit of 3.18 in control (no trap and no spray) proving the supremacy of deltamethrin as an insecticidal spray. The treatment with only ME traps resulted in a mean maggot emergence of 3.00 which was also significantly lower than of control.

The correlation between quality parameters at different stages of harvest (4WBH, 2WBH and at harvest) and the extent of infestation as indicated by number of maggots present in the fruit pulp indicated significant positive correlation with TSS ($r = 0.999058$) and significant and negative correlation with total acidity ($r = -0.99863$), fruit firmness ($r = -0.99892$) and peel thickness ($r = -0.9948$). The total sugar had a positive correlation with extent of infestation but was not significant.

The infested fruits were damaged in respect of edible pulp resulting in deterioration in biochemical parameters. The infested fruits had a reduction of 17.96 per cent in TSS, 8.33 per cent in reducing sugar and 16.54 per cent in non reducing sugar in comparison to healthy fruits, while the increase in acidity in the affected fruits was to the tune of 41.1 per cent against the healthy fruits.

The infestation by fruit flies caused a severe loss to the fruits during harvest which soared up to 80 per cent (Abdullah *et al.*, 2002) leading to substantial loss in the net return to the farmers. The percentage infestation differed significantly among the treatments. The total cost of cultivation did not differ much among the treatments since the cost of trap and the cost of insecticides and their application was not high in comparison to the total cost of cultivation. Since the yields were highly variable with deltamethrin application + trap resulting in 103.08 per cent increased in yield over the control treatment (T_7) it resulted in greater variation in both total return and net return. The net return varied from only Rs. 5400 ha^{-1} in the control and Rs. 37682 ha^{-1}in only ME trap i.e. T_6 to Rs. 99972 ha^{-1} in deltamethrin application + ME trap i.e. T_3.

Conclusion

In varieties Suvarnarekha and Amrapali fruit fly peak occurred in 19th SW and in varieties Dashehari, Langra, Alphonso and Mallika in 20th SW. Suvarnarekha with a mean number of maggots emergence of 6.4 per fruit had maximum per cent of infestation and Dashehari showed a minimum of 1.3 mean number of maggots. 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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