SPECIES DIVERSITY OF THE ORCHARD FRUIT FLY COMPLEX AND THE BIORATIONAL MANAGEMENT OF THE MANGO FRUIT FLY, *Bactrocera dorsalis* (Hendel) (Diptera: Tephritidae)

By

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THESIS

Submitted in partial fulfilment of the requirement for the degree of

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DECLARATION

I hereby declare that this thesis entitled **"Species diversity of the orchard fruit fly complex and the biorational management of the mango fruit fly, *Bactrocera dorsalis* (Hendel) (Diptera: Tephritidae)"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title, of any other University or Society.

Place: Vellanikkara
Date: 13.05.2008

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CERTIFICATE

Certified that this thesis, entitled **"Species diversity of the orchard fruit fly complex and the biorational management of the mango fruit fly, *Bactrocera dorsalis* (Hendel) (Diptera: Tephritidae)"** is a bonafide record of research work done independently by **Mr. Thiyagarajan, P.** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

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Introduction

1. INTRODUCTION

Fruit fly species of the subfamily Dacinae (Diptera : Tephritidae), are one of the most serious group of pests in different horticultural ecosystems. They cause tremendous economic losses and produce great havocs in production systems of both fruits and vegetables all over the world. Out of the 320 species so far recorded from the Indian subcontinent, only a few of them are a matter of concern and these are mostly under the genera *Bactrocera* and *Dacus* (Kapoor, 1991). The annual loss caused by the fruit flies belonging to these two genera is estimated to be around Rs.2,600 crores in India (Stonehouse, 2001).

They attack a wide variety of fruit crops like mango, orange, sapota, guava, papaya, ber, apple, etc. and vegetables like cucurbitaceous crops, tomato, brinjal, moringa etc. Among fruit flies, the oriental fruit fly (better known as orchard fly), *Bactrocera dorsalis* (Hendel) is the major and serious pest species and attacks more than 250 different kinds of fruit and vegetables (Kapoor, 1993).In orchard systems the fly causes heavy losses ranging from 20-30 per cent (Kalloo, 2005). It also heavily affects the quality of the fruits. Among the fruits, mango is the most preferred host of this fly and that is why it is also called as "mango fruit fly".

Mango, *Mangifera indica* L. occupies a prominent place among the fruit crops grown in India. It is the most popular homestead and orchard fruit tree crops among the farmers in Kerala, as it fetches higher yield and net profit. The mango has been ravaged by some of the insect pests right from the onset of flowering to fruit harvest. The mango fruit fly, *B. dorsalis* is highly destructive among them.

The recommended management practices against mango fruit fly in mango orchards include removal and destruction of affected and decayed fruits, raking up the soil under the trees to destroy their pupae, soil treatment and spraying insecticides. Often these measures are not found to be successful in checking the fruit fly because of the innumerous survival adaptations and mechanisms of the pest.

The distinct life cycle (Plate 1) of the fruit flies and their shifts among different fruit tree hosts render them less amenable for the conventional pest management measures. The female fruit fly lays the eggs beneath the fruit skin about 3 to 6 mm inside, using its long ovipositor. Developing larvae are also seen inside the fruit after ripening and hence, are inaccessible for natural control factors. The maggot nearing pupation have the habit of jumping out of the host fruit and move away from the surrounding of host plants. As a result, the pupae are very much get distributed in their habit and found below the soil at a depth of 0.5 to 20 cm and consequently, escape from the management practices. Besides, the adult flies spend most of their life span around the host environment and visit the host fruits for oviposition. Thus, the fruit flies have several adaptive factors favoring their survival and infestation potential.

Further, the strategy for the management of insect pests in fruit and vegetable crops should be essentially different from the other crops, because of the nature of utilization of the produce as direct or raw. This calls for extra caution especially in the usage of chemical insecticides, due to residue pervasion in fruits and environment, pest resistance to insecticides, adverse effects on pollinators and natural enemies of pests, secondary resurgence of minor pests and finally inviting all the consequent health and environmental hazards. There is greater need and demand to produce residue free fruits and vegetables like cucumber, mango, guava etc. which are eaten a fresh (Kalloo, 2005).

Hence, there is an impetus for research and development for cost effective and ecofriendly alternatives for the fruit fly management in orchard ecosystems. Biorational strategies employing different attractant traps are the possible alternative measures for the sustainable management of the fruit fly species complex especially in the present era of organic agriculture.

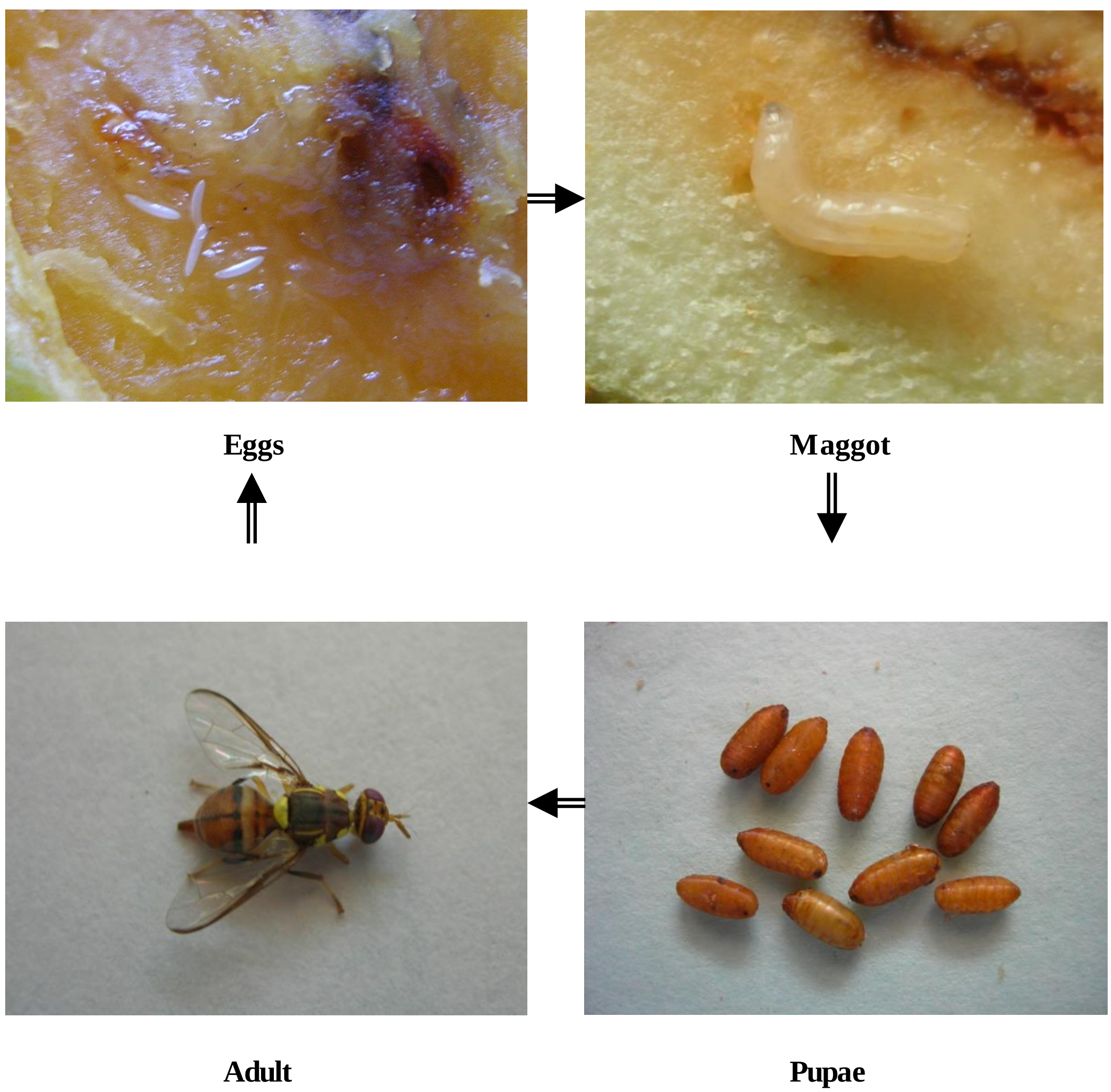


Plate 1. Life cycle of mango fruit fly, *Bactrocera dorsalis* (Hendel)

In this context, the present investigation is carried out with the following objectives.

- To study the diversity of fruit fly species complex in mango orchard systems and host fruits
- To study the population dynamics of the species under various agro ecological and geographical conditions during the main season and their spread, prevalence and survival mechanisms, and
- To evolve better biorational management strategies for mango fruit fly *B. dorsalis* for developing ecologically sustainable IPM strategies.

Review of Literature

2. REVIEW OF LITERATURE

Fruit flies comprise of over 4,000 species distributed world over. The genus *Bactrocera* consists of approximately 440 species, which are economically important pests of fruits and vegetables. They are distributed throughout tropical Asia, parts of China, Japan, Micronesia, Pacific Islands, Hawaii, Australia and some parts of Africa (Drew, 1989; White and Elson, 1992). The mango fruit fly, *B. dorsalis* is an important species in terms of its distribution, wider host range, rapid population build up and economic damage.

The strategy for fruit fly management mainly relies on the chemical pesticides. The unwanted use of chemical pesticides had resulted in the flare up of minor pests, destruction of natural enemies and other beneficial insects, pest resurgence, pesticide residue in food, contamination of the environment and related health hazards. Hence, an ecofriendly biorational approach is essential for the management of fruit fly in fruit crops.

The important works pertaining to population dynamics and biorational strategies in the management of fruit flies viz. use of different traps, lures and important natural enemies are reviewed in this chapter.

2.1 POPULATION DYNAMICS OF FRUIT FLIES

Population studies provide the key to a precise understanding of the natural abundance of the fruit fly and assist to evolve effective and timely pest management schedules. In the abundance and population build up of tephritid fruit flies, weather parameters and host availability play a major role (Fletcher, 1987). Pheromone traps provide an easy and efficient method to monitor the activities of fruit fly populations (Alyokhin *et al.*, 2000).

2.1.1 Species diversity and population dynamics

Verghese and Devi (1998) reported that the *B. dorsalis*, a serious pest of mangoes, was monitored using methyl eugenol traps at an experimental farm in

Karnataka. The trap catch was high during the months of May to August, which was synchronised with the maturity of several susceptible mango cultivars. The trap catch study carried out for two years was correlated with the abiotic factors and it was found that a significant positive correlation with minimum temperature and wind speed. The trap data of the first week could serve as an useful index to predict fruit fly population of subsequent weeks, especially 8th week with the maximum coefficient of determination equal to 36 per cent, based on a linear model. The coefficient of determination improved with a polynomial model to 39 per cent. Other non-linear models like logarithmic, power and exponential had lower coefficient of determination.

Adult males of *Bactrocera dorsalis* and *B. zonata* were trapped using the attractant methyl eugenol, bait (protein hydrolysate) and malathion insecticide between April and August 1997, at Pusa in Bihar, India. The average number of these flies trapped during the study period was 39.94 and 134.92 flies per trap per week, respectively. The average mean population of *B. zonata* was 3.38 times greater than that of *B. dorsalis*, which indicated the population suppression of *B. dorsalis* by *B. zonata* (Agarwal *et al.*, 1999a).

Mann (1996) observed that the *B. dorsalis* flies were recorded throughout the year in methyl eugenol baited traps in a mango orchard in Ludhiana, Punjab, India. Population counts were low in the winter months from December to February which was thought to be caused by low temperature (below 20°C). Following the warmer season, the flies could rebuild their population throughout the rest of the year. However, low catches in July may be due to the after-effects of high temperatures in June (31.93°C) or due to high rainfall (223 mm/month). Afterwards, increases in fruit fly catches might be attributed to conducive temperature (24-29°C) and abundant supply of host fruits. The fruit fly counts on the mango fruits during July were greatest at 1100 h and 1200 h. Fruit fly infestation was 30.77, 65 and 85.50 per cent in cultivars Dusheri, Sucking and Chausa, respectively.

Jayanthi and Verghese (1998) observed hourly fluctuations in trap catch (baited with methyl eugenol + carbaryl) of *B. dorsalis* in a mango orchard in

Karnataka, India. Catches were maximum in the afternoon, with a peak between 16.00 and 17.00 h. There were no catches between 17.00 h and 19.00 h.

Four species of fruit flies, viz. *Bactrocera correcta, B. cucurbitae, B. dorsalis* and *B. zonata*, were recorded in methyl eugenol traps installed in cucurbit fields in Ranebennur, Haveri, Karnataka, India, from August 2001 to January 2002. *B. dorsalis* and *B. cucurbitae* were the dominant species, comprising 48 and 21 per cent of the total catch. Irrespective of the species, the maximum catch of fruit flies occurred during the 14th standard week, i.e. first fortnight of November (Babu and Viraktamath, 2003a).

Investigations on seasonal activity showed that the population of *Dacus zonatus* [*Bactrocera zonata*] was higher than that of *Dacus dorsalis* [*Bactrocera dorsalis*] throughout the activity season in 1997 in mango in Pakistan. The highest male population of *Dacus* spp. was observed in the first week of July (Suhail *et al.*, 2000).

Field studies on the annual population incidence of *B. dorsalis* were conducted in a pear orchard at Peshawar, Pakistan, from January-December 1986 using bait traps containing methyl eugenol. No fly activity was observed in January-March. From April onwards, the population started to build up and a peak was reached in July with 145.75 flies/week. The population then got declined from August-November and there was no activity in December. There was a positive correlation between fly population and fruit infestation (Khattak *et al.*, 1990).

Traps baited with cuelure or methyl eugenol were investigated for monitoring *Dacus* [*Bactrocera*] spp. in Nauru in December 1993. Over a period of three days, the number of flies caught per trap averaged 2237.2/day with cuelure, catches being highest at the east coast of the island. With methyl eugenol, catches averaged 1114.7/day, and traps at the east coast and near a small lake in a central area were highest only. *D. frauenfeldi* [*B. frauenfeldi*] comprised of 99.9 per cent of the catch with cuelure, whereas *B. dorsalis* and *B. frauenfeldi* comprised 47.6 and 51.6 per cent, respectively, of catches with methyl eugenol. Smaller numbers of *D. cucurbitae*

[*B. cucurbitae*] and *D. xanthodes* [*B. xanthodes*] were caught. After three days all the 21 of the traps used were removed to a demonstration farm of area less than two ha. After about one month's trapping at a demonstration farm of less than two ha area with 21 traps, the numbers of flies attracted decreased significantly (Chu *et al.*, 1994).

Populations are always high from July to September, especially in mountain areas. The population dynamics of the fruit fly in different habitats including economic and non-economic cultivated areas were investigated. The results showed that the population density of the fruit fly in a swamp oak (non-economic) area was higher than that in a wholesale market (non-economic area) and a pomelo cultivation area (economic area). The former density was about 4-16 times higher than those of the latter. Changes in population dynamics were stable in the swamp oak and pomelo cultivation areas, but they showed greater fluctuations in the wholesale market. This phenomenon may have resulted from the instability of the host supply in the wholesale market (Chen *et al.*, 2002).

Based on horizontal and vertical catches in sex attractant traps and laboratory and field investigations, it was found that there are 4-5 generations of *B. dorsalis* annually in Yunnan Province, China. The second generation was the most important, feeding on mango, peach and guava fruits. The peak period of adult catches was during June-July, with the exceptions of citrus and sweet orange orchards (September-October and October-December, respectively.). The peak period and number of adult occurrences differed between years. During the same year, the peak period was delayed gradually from south to north, coinciding with the mature periods of fruit trees. In winter, adults were caught at all the sites, except the Kunming Area, with the largest population being caught in Xishuangbanna, an area with high temperature and humidity (Zhiying *et al.*, 1995).

Bait and pheromone traps were used to monitor three species of tephritids in six habitats in the Guangzhou area of China during 1989-92. Population densities were found to be highest for *Bactrocera cucurbitae* (causing serious damage to bitter melon [*Momordica charantia*]), lowest for *B. dorsalis* (damaging guavas), and intermediate for *B. tau* (damaging pumpkin). All three species had two density peaks per year. Peaks for *B. cucurbitae* and *B. dorsalis* were in January-March and July-November, and those for *B. tau* were in January-May and October-December. Density of *B. cucurbitae* was the highest in habitats where the fruit trees and vegetables were together cultivated or the cucurbits and vegetables were commercially grown in part of the area. Basically, the seasonal abundance of the tephritids coincided with the harvest of their hosts (HaiDong *et al.*, 1995).

The population dynamics of three fruit flies, the fig fruit fly, *Silba virescens*, the medfly, *Ceratitis capitata* and the peach fruit fly, *Bactrocera zonata* was studied in fig orchards at the northwestern coastal region of Egypt during three successive seasons- 1996, 1997 and 1998. The rate of infestation of *S. virescens* was estimated and the number of pupae and flies in fallen fruits and on standing fruits on trees were recorded. *S. virescens* existed in fig orchards from May to September, *C. capitata* from July to December, while *B. zonata* from August to December. During 1996, the numbers of captured flies/trap per day (CTD) of S. virescens and C. capitata were 0.02-6.67 and 0.02-9.73, 0.07-1.07 and 0.04-0.44 flies when diammonium phosphate (DAP) and fresh local attractants (FLA) were used, respectively. During 1997, the CTD of *S. virescens, C. capitata* and *B. zonata* were 0.04-3.40, 0.02-1.27 and 0.04-0.69; 0.07-4.73, 0.07-1.93 and 0.02-1.49; and 0.04-0.49, 0.02-0.11 and 0.02-0.07 flies by using DAP, FLA and old local attractant (OLA), respectively. In 1998, CTD for the three respective flies were 0.04-0.51, 0.07-0.60 and 0.02-0.22; 0.07-1.93, 0.04-0.40 and 0.02-0.13; and 0.04-0.93, 0.02-0.22 and 0.02-0.09 flies by using DAP, FLA and OLA, respectively. *S. virescens* infestation was 12.7, 8.8 and 4.4 per cent during the three successive seasons, respectively. During the period from May to August 1997 and 1998, from the incubated fig fruits *S. virescens* only emerged (182 and 299 flies from fruits on trees, and 118 and 126 flies from fallen fruits, respectively). Throughout the period from September until November 1997 and 1998, from the incubated fallen fruits *C. capitata* and *B. zonata* (353, 93, 212 and 211 flies, respectively) were emerged (Saafan *et al.*, 2000).

Hui and Ye (2001) reported that the geographical distribution of Oriental fruit fly in the region could be plotted as three distribution zones. To the south of Guannan, Yuanjiang and Rulin is the annual distribution zone. In this region, the Oriental fruit fly completed four to five generations per year, and infested the local vegetables and fruits all through the year. To the north of Luku, Dayiao and Qujing, where the oriental fruit fly was not trapped and no fruits infested by the fly. The region between the above two zones was the seasonal distribution zone for the insect. The fruit fly occurred only during May to December in this area, and completed two to three generations in this period. The peak abundance of the oriental fruit fly took place from June in Jinghong to October in Yiaoan, along the altitude graduates from the south to the north. In elevation, the Oriental fruit fly was trapped at altitude of 500-2300 m above sea level, in which high trap catches appeared between 500-1000 m. It is proposed that the variations of the fruit fly distribution in altitude and latitude are principally correlated with local temperatures and host plants.

2.1.2 Fruit flies and environment

The fruit fly (*B. dorsalis* and *B. zonata*) population was monitored with the help of bottle traps containing 100 ml aqueous solution of methyl eugenol (0.1%) and malathion (0.25%) per trap, in mango and guava orchards of submountain regions of Himachal Pradesh, India. The maximum catch of 98.6 and 62.6 males/trap for mixed population was recorded during 30th and 27th standard weeks in 1992 and 1993, respectively, in mango orchards. The corresponding catch in guava orchard was 427.2 and 517.0 during the 37th and 39th standard weeks. There was a significant positive correlation between the trap catch and maximum and minimum temperatures during both the years on both the hosts. The maximum catch coincided with the ripening period of fruits (Gupta and Bhatia, 2001).

B. dorsalis was the dominant fruit fly among the four species (including *B. zonata*, *B. correctus* and *B. cucurbitae*) captured in methyl eugenol traps established in mango orchards in Kumbapur and Hulkoti, Karnataka, India, during 2002. The peak catches of this fruit fly were recorded during the 21st, 23rd and 46th

standard weeks. Maximum infestation reached up to 30 per cent damage (0.75 larvae per fruit). *B. zonata* and *B. correctus* populations had significant correlation with temperature, while, *B. dorsalis* and *B. cucurbitae* populations had non-significant correlation with weather parameters (including relative humidity and rainfall) (Babu and Viraktamath, 2003b).

The peak population of *B. cucurbitae* and *B. zonata* was 395.6 and 297.3 per trap during the twenty-third standard week with methyl eugenol and cue-lure, respectively, during 2002 in Kanpur, India, while the peak population was 423.3 and 396.3, respectively, during 2003 in the twentieth standard week. There was a significant positive correlation between population dynamics and maximum temperature during 2002. The population of *B. zonata* also showed a significant correlation with minimum temperature during 2002, whereas the population of *B. cucurbitae* was significantly correlated with maximum temperature in both years. The maximum and minimum relative humidity and rain was negatively and insignificantly correlated during both the years, except with minimum relative humidity and rain during 2003 in cue-lure and rain during 2003 in methyl eugenol (Manzar and Srivastava, 2004).

Jalaluddin *et al.* (2001) studied the population fluctuations of the guava fruit fly, *B. correcta*, which was conducted in guava orchards in Tamil Nadu, India from May 1994 to September 1995 using methyl eugenol traps. A distinct population peak, which coincided with the ripening, was recorded from July to August in both years. Abiotic factors played an important role in regulating *B. correcta* population. Data on weekly catch when correlated with weather parameters showed significant positive correlation with mean maximum temperature ($r = 0.3314$), minimum temperature ($r = 0.3610$), day-degrees (thermal units) ($r = 0.3692$), morning relative humidity ($r = 0.4369$) and rainfall ($r = 0.2364$). Weekly mean sunshine hours had low negative correlation with the catch.

Agarwal *et al.* (1995) had studied the effects of maximum and minimum temperature and relative humidity on the population dynamics of *B. dorsalis* in northern Bihar, India, in 1990-91. The pest population was not affected by relative humidity; however, it was the highest when the temperature was between 25 and 38°C, and significant positive correlations were observed between maximum temperature and pest population, and minimum temperature and pest population.

Agarwal *et al.* (1999b) studied the population dynamics of peach fruit fly, *B. zonata*, were conducted during April-August 1997 in northern Bihar, India. Maximum fly populations were observed during the third week of June (357.0 flies/trap), whereas the lowest numbers were observed during the last week of August (14.3 flies/trap). Fly populations showed a positive correlation with maximum and minimum temperatures, rainfall and a negative correlation with relative humidity.

Changqing *et al.* (1995) studied the population growth of *B. cucurbitae, B. dorsalis* and *B. tau* under different photoperiods (LD 16:8 to 8:16) at constant temperature (25°C) and fluctuating relative humidity (75-95%), and under cyclically fluctuating temperatures, relative humidity and stable photoperiods (20-25°C, LD 4:10, RH 75-95% and 25-32°C, RH 75-95%, LD 10:14), medium and long photoperiods were suitable for reproduction. Short photoperiods were less suitable. Population parameters (either under the circumstances of various photoperiods with constant temperature and fluctuating relative humidity or under cyclical fluctuating temperatures and relative humidity with constant photoperiod) of all three tephritids showed longer ovipositional periods, large numbers of eggs laid and overlapping generations. The population growth of *B. tau* and *B. dorsalis* was more rapid than that of *B. cucurbitae*. *B. dorsalis* and *B. tau* are recognized as more typical of an r-type reproductive strategy than *B. cucurbitae*.

The kairomones (methyl eugenol, cue-lure), sugar and naled were blended in a per cent ratio of 85:10:5, respectively, and five ml of the preparations were impregnated on cotton in a trap. Methyl eugenol baited traps were placed in peach/apricot orchards, while cue-lure baited traps were placed near vegetable fields in Pakistan. Males of *B. dorsalis* were attracted to the methyl eugenol baited traps from May to October during 1985 and 1986. Peak abundance occurred during July.

The kairomone remained residually effective until the next season. The cue-lure baited traps attracted *B. cucurbitae* males from mid-July to mid-November, with a peak in August, and from the second week of August to the second week of November, with a peak in September, during 1985 and 1986, respectively. Significant and non-significant positive associations were found between numbers of *B. dorsalis* and temperature, RH and rainfall, and the total of mean temperature, RH and rainfall. A significant/non-significant positive relationship was noted between numbers of *B. cucurbitae* and temperature and humidity and their total during 1985, but rainfall had a weak negative correlation. During 1986, temperature had a non-significant positive association but other parameters had a weak to moderate negative relationship (Zaman, 1995).

Sobrinho *et al.* (2002) revealed that greater acreage and host diversity of edible fruits were highly preferred by fruit flies, especially *C. capitata*. The population of *C. capitata* and *Anastrepha* sp. increased during the rainy season. The Fly Trap Day index in 2001 was seven fold higher than in 2000. Most fruit fly catches were from fruit orchards and urban areas rather than from melon fields. The hydrolysed protein in McPhail traps was highly efficient in the capture of fruit flies; however, these traps, besides being cumbersome to deploy, attracted large number of other insects.

2.1.3 Species and host distribution

Tan and Serit (1994) estimated native male population, new recruits (young indigenous and immigrant flies) and survival rate of *B. dorsalis* , by mark-release-recapture technique using methyl eugenol-baited traps, in two villages in Penang, Malaysia. Population size and new recruits were significantly higher in Tanjong Bungah (TB) than in Batu Uban (BU). This was caused by the higher number of fruits damaged in TB, although BU had more varieties of fruit trees. However, survival rate of fruit flies in both villages was the same. The most important component of the environment affecting adult populations of *B. dorsalis* in the tropics is the availability of suitable host fruits. In both villages, among a variety of host plants grown, star fruit played the most important role in this regard. The abundance of damaged fruits fluctuated and lagged behind estimated populations and new recruits of *B. dorsalis* males by three to five and two to four weeks, respectively. Peak numbers of *B. dorsalis* males and host fruits occurred entirely within the wet seasons of the year. During dry seasons, the fly population declined because of less fruit. However, rainfall (as well as temperature, relative humidity, and wind speed) had no significant correlation with estimated *B. dorsalis* male population parameters or host fruit abundance.

The population monitoring of fruit fly species and their infestation were studied by installing methyl eugenol and cue-lure traps for two years (2001 and 2002) in apple orchards of Murree hills (Pakistan). The second year collection was identified. The data on infestation percentage were recorded by iron ring method. The cotton wicks were changed fortnightly in methyl eugenol traps. Population of fruit flies ranged from 0.37 to 1.62 per trap per day on first October and first August, respectively. The population remained present throughout the fruiting season from flowering to maturity. The maximum infestation of fruit flies in apple orchards was recorded to be 4.61 per cent on first October and was statistically at par with 4.53 and 4.51 per cent recorded on 15th September and 15th October, respectively. The methyl eugenol traps showed maximum number of adult fruit flies. *B. dorsalis* was dominant on apple. The correlation between population and per cent infestation of fruit flies was non-significant (Khan *et al*., 2003a).

The population of *Bactrocera* fruit flies was surveyed from September 1997 to September 1999 in Sri Lanka using stiner-type traps with two kinds of lure (methyl eugenol and cue-lure) in one fixed point. Fifteen species of *Bactrocera* fruit flies were captured in total. *B. dorsalis* and *B. kandiensis* were dominant in traps with methyl eugenol, and *B. cucurbitae* and *B. nigrofemoralis* were captured mainly by cue-lure. The populations of fruit flies were not high every year, even in a tropical zone such as Sri Lanka. In particular, a few fruit flies were captured from September 1997 to March 1998, and from September to December 1998. *B. correcta* was found in traps by using methyl eugenol from October to February, and *B. zonata* were attracted by methyl eugenol from April to July. A small number of two other species by methyl eugenol, and seven species by cue-lure were captured occasionally. In particular, only one male of *B. apicofuscans* was collected, on 30th April 1998 (Kawashita *et al*., 2004).

Population monitoring of fruit fly species and fruit infestation were conducted by installing methyl eugenol and cue lure traps for two years (1998 and 1999) in Sheikhupura, Pakistan. The second year collection was identified. The data on infestation percentage were recorded by iron ring method. The cotton wicks in methyl eugenol traps and wooden plates with baiting material were changed fortnightly. The second fortnight of August and first fortnight of September showed maximum population trapped by pheromones in guava orchards. The population of fruit flies was present throughout the fruiting season from flowering to maturity. The methyl eugenol traps showed maximum adult fruit flies population in orchards located in Sheikhupura during the 2 fruiting years. *B. zonata* was dominant on guava with 49.62 per cent, followed by *B. dorsalis* with 46.37 per cent (Khan *et al*., 2003b).

Twelve cucurbits namely cucumber [*Cucumis sativus*], melon [*Cucumis melo*], watermelon [*Citrullus lanatus*], round gourd [*Citrullus lanatus* var. *fistulosus*], bottle gourd [*Lagenaria siceraria*], smooth gourd [*Luffa aegyptiaca*], ridge gourd [*Luffa acutangula*], bitter gourd [*Momordica charantia*], pumpkin [*Cucurbita moschata*], long melon [*Cucumis utilissimus*], ash gourd [*Benincasa hispida*], snake gourd [*Trichosanthes cucumerina*] and pointed gourd [*Trichosanthes dioica*] were tested for the relative population and host preference of fruit fly (*Bactrocera dorsalis*). The maximum emergence of fruit flies were found in melon and bottle gourd, and minimum in round gourd. The long melon was recorded as the most preferred host, bitter gourd as preferred host, melon and round gourd were categorized as moderately preferred host while cucumber, bottle gourd and snake gourd were recorded as least preferred hosts (Rajpoot *et al*., 2002).

B. dorsalis and *B. correcta* were trapped in northern and central Thailand, *B. papayae, B. carambolae* and *B. umbrosa* were restricted to southern Thailand and Malaysia, while *B. cucurbitae* was widespread, although more abundant in the north.

B. dorsalis, B. papayae and *B. correcta* exhibited unimodal patterns of population abundance, with populations peaking between June and September depending on species and locality. *B. carambolae, B. cucurbitae* and *B. umbrosa* showed no clear patterns in their population modalities, varying between regions. Based on fruit rearing work undertaken in northern and southern Thailand, information on host use patterns is also provided for the above six species, and *B. latifrons*. *Bactrocera umbrosa*, *B. latifrons* and *B. cucurbitae* are confirmed as oligophagous on *Artocarpus* spp., *Solanum* spp. and *Cucurbit* spp., respectively. Species of the *B. dorsalis* complex (*B. dorsalis, B. carambolae, B. papayae*) and *B. correcta*, although with a very wide potential host range, were predominantly reared from a small number of hosts, including *Terminalia catappa*, *Psidium guajava*, *Syzygium samarangense* and *Averrhoa carambola*. The number of flies reared from such hosts were generally in excess of the proportion of that fruit in regional samples, implying that even though the flies are polyphagous species, not all hosts are used equally (Clarke *et al*., 2001).

The population fluctuation studies of oriental fruit fly showed that daily maximum and minimum numbers trapped was 410 flies per trap in June and four flies per trap in January. The released sterile flies, irradiated at 90 Gy, were not able to compete with normal flies in a mating competition (competitiveness = 0.77). The number of sterile flies, which should be released to eradicate the Oriental fruit fly, was 39,312 males per km per week (Keawchoung *et al*., 2000).

Harris *et al*. (1995) reported marked temporal differences in peak trap catches of the tephritid in lowland areas compared with upland areas. Adults were caught in two upland locations compared with catches in six lowland locations. Strawberry guava (*Psidium cattleianum*) and common guava (*Psidium guajava*) form a discontinuous belt of plants around Kauai. Infestation of this fruit by *C. capitata* was nearly absent in wet areas, and consistent but variable in dry areas. The seasonal appearance of *C. capitata* in traps in Kokee and Polihale coincided with their emergence from collected fruits. The mean infestation rate of *C. capitata* in guava was 0.43 ± 0.27 (mean ± SEM) per kg of fruit, compared with 37.5 ± 15.3 for *B. dorsalis*. Infestation of all fruits collected by *B. dorsalis* was widespread in all areas when these plants produced ripe fruits. The attack of *C. capitata* was very limited in comparison with the distribution and abundance of food plants.

Vargas *et al*. (1992) found that the capture rates of *B. dorsalis* were higher outside than inside pawpaw orchards, while the reverse was true for *B. cucurbitae*. During periods of peak guava abundance, numbers of *B. dorsalis* increased in orchards, while those of *B. cucurbitae* increased in habitats around orchards.

Qureshi *et al*. (1991) studied the relative abundance of *B. zonata* and *B. dorsalis* in six varieties of mango. The pupal recovery and pupal survival from infested fruit (1 kg) showed that cultivars Sonehra and Beganapalli were preferred over cultivars Sindhri, Desi, Almas and Langra. The population of *B. zonatus* was higher than those of *B. dorsalis* in all varieties but the relative preference of both the species was very similar. Trap catches in mango orchards in Pakistan also showed a dominance of *B. zonatus* over *B. dorsalis*. Adult fly populations were at their peak during fruit maturation in June.

Strawberry guava (*Psidium cattleianum*), widespread in Reunion Island, is a major host plant for different fruit fly species. Relations between fruit fly population dynamics, host phenology and fruit infestation were studied. Seasonal occurrence of fruit flies was determined by male trap captures from 1992 to 1994 in three natural areas invaded by *P. cattleianum* located at elevations of 100 m, 480 m and 720 m on the wet windward coast of the island. Strawberry guava fruit infestation was monitored during harvest. The major fruit fly species captured at all sites was the natal fruit fly, *Ceratitis rosa* Karsch. The Mediterranean fruit fly *C. capitata* (Wiedemann) and the Mascarenes fruit fly *C. catoirii* (Guerin-Meneville) were occasionally trapped at elevations of 100 m and 480 m. Strawberry guava is a host for these three species from sea level to an elevation of 500 m. Only *C. rosa* infested fruit at higher elevations and was the most important species. *C. rosa* populations were low during most of the year, but increased when strawberry guava fruit reached maturity. *C. rosa* abundance differed significantly between the sites, but without clear relation with elevation (Normand *et al*., 2000).

The subtropical fruit production on the Mediterranean coast of Granada is very important. Mediterranean fruit fly *C. capitata*, is the major pest in the area and is responsible for the majority of sprays on the fruit trees. A study was carried out of the evolution of the pest in several fruit trees throughout the year in four climatologically different localities of the area. The results showed differences between areas, the locality of Almunecar being the best area for the insect to grow and develop during the whole year. The colder localities are affected by the migration of flies coming from the warmer localities (Ros *et al.*, 1999).

2.2 EFFICACY OF DIFFERENT TYPES OF TRAPS AND LURES AGAINST FRUIT FLIES

2.2.1 Parapheromone traps

The males of many tephritid species were strongly attracted to specific chemical compounds termed para pheromones or male lures, which occur either naturally or are synthetic analogues of plant borne substances (Chambers *et al.*, 1972). Several well known examples of parapheromones include methyl eugenol (4-allyl-1,2-dimethoxybenzene) for males of oriental fruit fly, cuelure (4-(P-acetoxy phenyl)-2 butenone) for males of melon fly *B. cucurbitae* and trimedlure (t-butyl-4, (or 5)-cholro-2 methylcyclo hexane-1-carboxylate) for males of Mediterranean fruit fly, *C. capitata*. Owing to the powerful attraction, parapheromones were used in control programs of tephritid pests, detection and monitoring their populations and for eradication via male annihilation (Shelly and Villalobos, 1995). The male annihilation technique involved the use of a high density of bait stations consisting of a male lure combined with an insecticide (usually malathion), to reduce the male population of fruit flies to such a low level that mating practically does not occur.

The first male attractant developed for male fruit flies was methyl eugenol against *B. zonata* (Howlett, 1912). Beroza *et al.* (1960) demonstrated cuelure as an effective attractant for *B. cucurbitae*. Trimedlure, the parapheromone for Meditterranean fruit fly, *C. capitata* was discovered by Beroza *et al.* (1961). Hardy (1979) estimated that at least 90 per cent of the Dacinae fruit flies were strongly attracted to either methyl eugenol or cuelure. Males of at least 176 species of Dacinae were found to be attracted to cuelure and 58 species to methyl eugenol (Metcalf, 1990).

By using methyl eugenol together with the insecticide naled, Steiner *et al*. (1965) eradicated oriental fruit flies from the island of Rota by dispersing fibre board squares imprenated with 25 mg of methyl eugenol (97%) and naled (3%), at the rate of 115 per square mile. The same success story was replicated in Mariana Islands (Steiner *et al*., 1970) and Okinawa Island (Koyamer *et al*., 1984). In Hawaii, male annihilation using cuelure and naled reduced the population of *B. cucurbitae* by 99 per cent throughout a 5.2 square km plot for more than seven months (Cunningham and Steiner, 1972).

Verghese (1998) noted that the methyl eugenol, which was categorized as a bait for male tephritids, was also found to attract a small number of females of *B. dorsalis* during the active breeding time in a mango orchard at Bangalore, Karnataka, India, in May-June 1998. At the time of harvest, number of males and females trapped were in almost equal proportions. The potential of these findings helped for avoiding post-harvest mango losses due to *B. dorsalis* was appreciable.

The efficacy of methyl eugenol, molasses and ethyl benzoate as baits for trapping *B. dorsalis* were compared during 2-18 May, 1995 at the butterfly park of Taipei Municipal Zoo, Taiwan. No flies were caught by the molasses trap. No female flies were attracted by methyl eugenol, but a total of 300 males were trapped. Although ethyl benzoate caught some of the flies, the majority of them were males. Ethyl benzoate also attracted *Acrotaeniostola sexvittata*, an insect pest of bamboo sprouts (Chu *et al*., 1996).

Eight out of 44 selective analogues of veratrole, showed as promising attractancy for males of *B. dorsalis* in week-long field tests in Hawaii when compared with a standard methyl eugenol (ME) lure. 4-Propyl- and 4(and 5)-allyl-2-ethoxy-1-methoxybenzene were the most effective of the eight promising lures showing high levels of initial and persistent attraction. 4-Ethyl-2-ethoxy-1-methoxybenzene showed high level of initial attraction but lacked persistence as did its corresponding dimethoxy analogue. High levels of attractancy demonstrated by several analogues evaluated in this study suggested that they could serve as potential alternatives to ME, if a critical need arises and their toxicity was acceptable. Despite previous studies showing that 889 chemicals were attractive to *D. dorsalis* in olfactometer tests, only 3 of the chemicals showed promise in the field (Demilo *et al.*, 1994).

Mahmood *et al.* (1995) used dipterex [trichlorfon], Nogos [dichlorvos] and Decis [deltamethrin] either alone and in combination with methyl eugenol-baited traps against *B. dorsalis* in the Bannu district of North West Frontier Province, Pakistan. They found that trichlorfon was the most effective insecticide, followed by dichlorvos and deltamethrin. The best results were achieved when all the three insecticides were used in combination.

Methyl eugenol-baited traps were used for oriental fruit fly (*B. dorsalis*) control through male annihilation, as well as for detection and monitoring of fly populations. However, if the males which come to these traps emit sex pheromones, attract females from the surrounding vegetation, and mate with them before being killed, then using such traps might in fact increase levels of fruit infestation. A study conducted between 28 April and 13 June 1999 monitored fly abundance in experimental orchards (containing grapefruit, mandarin and shaddock [pummelo] trees) before, during and after methyleugenol-baited trap deployment at two sites in Kauai, Hawaii, USA.. They recorded the numbers of flies recruited to the trees with and without traps, and quantified their sexual activity. The males attracted by methyl eugenol fed on the poisoned baits almost immediately upon their arrival, and did not attempt to emit pheromones or attempt copulations before entering the traps were recorded. No changes in female abundance in the vicinity of deployed traps were recorded. Because of their high specificity, low cost and environmental safety, methyl eugenol-baited traps might be a valuable tool for integrated management of oriental fruit fly populations (Alyokhin *et al.* (2001).

Methyl eugenol was an extremely effective attractant for male oriental fruit flies, *B. dorsalis*. Field experiments were conducted in a commercial guava (cv. Beaumont) orchard in Kauai, Hawaii, USA, during 1996 and 1997, to determine whether the presence of methyl eugenol-baited traps affected the distribution and abundance of female oriental fruit flies near the traps. Captures of females on spheres did not increase within the vicinity of methyl eugenol-baited traps. Captures of males were significantly greater on spheres hung in trees containing methyl eugenol-baited traps than on spheres hung in other trees. An experiment was conducted to determine if methyl eugenol would influence the dispersal of unmated, sexually mature female oriental fruit flies. There were no significant differences in the numbers of marked or wild females captured on traps at different distances from the methyl eugenol lure. This study did not find any evidence that the presence of methyl eugenol-baited traps in orchards would affect female abundance in the vicinity of traps (Cornelius *et al*., 2001).

A two year study was made, for the protection of mango orchards from tephritid fruit flies by traps containing ME lures and food baits, of both manufactured and home made origin. Relative to unprotected plots, the infestation of mangoes by fruit flies was inferred to be reduced by MAT (Male Annihilation Technique), using a soaked plywood ME blocks by 21 per cent ; by MAT by home made materials as ocimum leaf traps by 15 per cent, by BAT (Bait Application Technique) using manufactured materials as PH traps by zero per cent and by BAT using home made materials as banana traps by 12 per cent. Only the manufactured MAT obtained statistically significant results. There was evidence of positive interaction when the two controls where used together, the manufactured MAT and BAT together obtaining an inferred reduction in infestation of 82 per cent (Thomas *et al.*, 2005).

Methyl eugenol (4-allyl-1,2-dimethoxybenzene-carboxylate) and cuelure [4-(p-acetoxyphenyl)-2-butanone] are highly attractive kairomone lures to oriental fruit fly, *B. dorsalis*, and melon fly, *B. cucurbitae*, respectively. In an experiment conducted from October 1991 to August 1992, plastic bucket traps were evaluated as dispensers for methyl eugenol and cuelure for suppression of these two fruit flies in

Hawaii, USA. Methyl eugenol and cue-lure mixtures were compared with pure methyl eugenol or cuelure over four seasons. *B. dorsalis* captures differed significantly with treatment and season. *B. dorsalis* captures with 100 per cent methyleugenol were significantly greater than all other treatments at 25, 50, and 75 per cent. *B. cucurbitae* captures also differed significantly with treatment but not with season (Vargas *et al.*, 2000).

In studies carried out in Maharashtra, India, the fruit fly trap (Trap-F) with methyl eugenol (3 ml/trap) and baited with 0.05 per cent dichlorvos (DDVP) was found to be the most effective and economical treatment against fruit flies (*Dacus* spp.) with the lowest percentage of fruit infestation, maximum yield and net returns/ha and greatest cost benefit ratio (1:47.8). Amongst the baited and non-baited sprays, DDVP + hydrolysed yeast + gur gave maximum protection to ridge gourd (*Luffa acutangula*), ranking sixth on the basis of the cost benefit ratio. Bait sprays of malathion (0.05%) + gur (1%) was the second most effective treatment in economical terms against fruit flies infesting ridge gourd (Deshmukh and Patil, 1996).

In field trials in 1986 in guava orchards in Pakistan, *B. zonata* and *B. dorsalis* were controlled by mass trapping of the males. Plastic gallon traps were baited with Eugecide-S [methyl eugenol] (4 ml/trap on a cotton wick) and the traps were placed on guava trees five feet above the ground at a density of one per acre. One week after the traps were placed, the number of males trapped in a single trap/week was reduced to 424.0 for *B. zonata* and 2.67 for *B. dorsalis* compared to 2309.67 and 27.00 in the control orchard. This reduction (77.37 and 80.48%, respectively) was sustained throughout the season as the populations reduced naturally. The number of larva-infested fruits was reduced by 24.14 per cent. This relatively small reduction was apparently due to the immigration of gravid females from nearby orchards, and it is suggested that if all orchards in an area were treated this larval infestation would be reduced (Marwat *et al.*, 1992).

Experiments were carried out in 1992 to 1993 in Jammu and Kashmir to study the effect of methyl eugenol baited with dichlorvos for the control of *B. dorsalis* in guava orchards. Five different concentrations were tested. The pest control was highest with methyl eugenol (1%). *B. dorsalis* population peaked during 20th July to third August, which almost coincided with fruit ripening. There was overall 51 per cent reduction in fruit damage where methyl eugenol traps were used. In the orchards where the traps were used, 16 per cent of the fruits were damaged on fourth September compared with 82 per cent in the controls. Highest trap catch (170.66) was obtained in the 6th week (20-27th July) when maximum and minimum temperatures were 33.6 and 25.5°C and relative humidity was 90.3 and 57 per cent, respectively (Makhmoor and Singh, 1998).

2.2.2 Food Lures

Liu and Hwang (2000a) were selected and tested twenty-one constituents of fruits from guava (*Psidium guajava*), mango (*Mangifera indica*), citrus (*Citrus grandis*) and carambola (*Averrhoa carambola*) in the screen house to determine the most attractive compounds for luring the oriental fruit fly, *B. dorsalis*. Results showed that methyl anthranilate (MA), alpha-terpineol (alpha T), ethyl acetate (EA), ethyl butyrate (EB) and cinnamyl alcohol (CA) were the most attractive to both female and male flies. Results also showed that 50 per cent molasses was the best concentration in attracting the flies. Results showed that the mixture of 50 per cent molasses and ethyl butyrate (25:1) was the most attractive one and was 1.8 times more attractive than 50 per cent molasses used alone. The mixture of molasses and ethyl acetate was also more effective than 50 per cent molasses. When two constituents were mixed with each other, it was shown that the mixtures of alpha T + EA, EA + EB, alphaT + EB, EA + CA and MA + EB attracted more adult flies than the other mixtures.

A bait trap (0.5 g Dipterex 80 SP [trichlorfon] per 100 g sweet gourd mash), an insecticidal spray (0.1% Dipterex 80 SP), and a bait spray (1.0 g Dipterex 80 SP + 100 g molasses/litre of water) gave a statistically similar level of control of *Bactrocera cucurbitae* attacking snake gourd (*Trichosanthes anguin* [*T. cucumerina*]) and kept the pest infestation within 4.9 to 8.6 per cent as compared to 22.5 per cent in the untreated control in farmers' fields during the kharif season in

Bangladesh. The above treatments showed 61.9 to 78.4 per cent reduction in infestation over the untreated control. Captures of fruit flies in bait traps showed 1.6 times more females than males (Nasiruddin and Karim, 1992).

Elshahaat *et al.* (1996) prepared six grades of Egylure using sugarcane molasses, soft yeast and other substances, and compared with the commercial attractant Buminal. All the prepared attractants and Buminal were miscible with water at different dilutions: 20, 10 and 5 per cent. These dilutions markedly decreased the surface tension value of water. The attractants were compatible with dimethoate and water in a 1:1:18 v/v mixture. The pH values were acidic in the range 4.9-5.1. The attraction per cent of *Ceratitis capitata* adults under laboratory conditions were 37.50, 35.39, 29.68, 29.17, and 28.34 per cent for Buminal, Egylure I, Egylure VI, Egylure IV and Egylure III, respectively. Under field conditions in Egypt, Egylure II and Egylure III were highly effective attractants, capturing 14.51 and 15.11 flies/trap per day, respectively.

The attractiveness of 50 per cent molasses attractant mixed with the volatile constituents of host fruits ethyl acetate (EA) and ethyl butyrate (EB) to Bactrocera dorsalis were studied in the screen house. Results showed that 50 per cent molasses mixed with ethyl acetate(EA) and ethyl butyrate (EB) at the ratio of 5:5 had higher attraction of 54.7 per cent to adult flies. With 50% molasses mixed with EAEB by various mix ratios, it was shown that the best mix ratio of mixture was 100:1 (MEAEB), with a high attraction of 60.5 per cent and females were attracted more than males. Addition of surfactant AG420 and dispersing agent (alcohol) to MEAEA mixture, increased the solvency of mixture without reducing the effectiveness. However, by adding surfactant without dispersing agent reduced the effectiveness of the mixture. The effective duration of the improved attractant MEAEB was tested in the screen house. The results showed that the per cent attraction to the flies was over 60 per cent during the first six days, and maintained at 45-55 per cent to the 10th day. Over 15 days, the attractiveness of MEAEB was higher than that of 50 per cent molasses, and mixing of ethyl acetate and ethyl butyrate with 50 per cent molasses could increase the effectiveness of 50 per cent molasses to the oriental fruit fly for the first 10 days. Accordingly the results from carambola [*Averrhoa carambola*] orchard testing showed that the attractiveness of the improved attractant MEAEB was 4.5 times higher than that of 50 per cent molasses, indicating that the volatile constituents of host fruits (ethyl acetate and ethyl butyrate) mixed at the best ratio with 50 per cent molasses should greatly increase the effectiveness of 50 per cent molasses for luring oriental fruit flies in the field (Liu and Hwang, 2000b).

Dwivedi *et al*. (2002) evaluated the four attractants, viz. jaggery, gur, methyl eugenol and combination of jaggery + babul gum (*Acacia nilotica*), at a guava orchard in and around Allahabad, Uttar Pradesh, India. Each attractant was mixed with malathion (0.05%) and poured into troughs. All attractants were found to be good in trapping. The maximum numbers of fruit fly (Bactrocera dorsalis) were trapped by methyl eugenol followed by jaggery. Poor performance was observed in the gur attractant.

A cotton pad (0.3 mg) treated with 0.25 ml of the leaf extract of *Ocimum sanctum* was found to be a potent attractant for luring and trapping *Dacus ciliatus*, *B. zonatus*, *D. dorsalis* [*B. dorsalis*] and *D. cucurbitae* [*B. cucurbitae*] from a distance of 0.8 km in orchards in Pakistan (Roomi *et al.*, 1993).

Satpathy and Rai (2002) assessed efficiency of indigenous food baits for attracting the adults of *B. cucurbitae* (infesting bitter gourd, *Momordica charantia*) under field condition. The bait containing pulp of overripe banana (1 kg) + Furadan [carbofuran] (10 g) + citric acid (1 g) was best in luring the fruit fly adults during its peak activity period. However, addition of sweet basil [*Ocimum basilicum*] leaf extract reduced the attractiveness of the bait. The bait remained effective up to 10 days after installation in the field.

A field experiment was conducted in India on snakegourd [*Trichosanthes cucumerina*] cv. Kaumudi to evaluate the efficacy of different food baits for the trapping of fruit flies, *Bactrocera* spp. Different combinations of treatments were made by combining the fruit pulp of banana cultivars Palayankodan, Robusta, Rasakadali and Red Banana; starch solution at 50 ml *Ocimum* spp. leaf extracts at 30 g in 50 ml water and jaggery [sugarcane] at 20 g, with boiled and unboiled jaggery at 10 g and carbofuran 3G at 2 g, or combinations of both. The flies caught were *B. cucurbitae* in most treatments, except in the treatment with Ocimum leaves where *B. dorsalis* was caught. The highest male count was obtained with Robusta + jaggery + carbofuran, while the highest female count was obtained with Red Banana + jaggery + carbofuran. The highest total fruit fly count was obtained in Robusta + boiled jaggery + carbofuran (Jiji *et al.,* 2003).

Solvent partitioning and chromatography were used to fractionate and purify extracts from seeds of *Annona squamosa*, producing at least seven isolates with varying degrees of polarity. The insecticidal activity against *Ceratitis capitata* of these extracts was evaluated in the laboratory and compared with that of unpurified and semipurified seed extracts of the same plant. Isolate FA, with an Rf value of 0.92, caused maximum mortality of 86 per cent, this isolate was also recovered in the largest amounts and was 2.5 x 10^{-3} and 2.07 x 10^{-3} as toxic as malathion to males and females, respectively It was thought that the polarity of these extracts may have influenced their toxicity to the test organisms; FA was apolar, probably penetrating through the cuticle and being carried by the haemolymph to the site of action, whereas the least toxic extract, FG, with an Rf of 0.01, was very polar and probably unable to penetrate the cuticle (Epino and Chang, 1993).

The efficacy of 12 commercial attractants, methyl eugenol (ME) board and four natural attractants placed in guava orchards to attract *B. dorsalis* were evaluated in Taiwan. All commercial attractants were less effective when compared to the attraction of males to ME boards and females to guava fruits. Guava fruits mixed with 90 per cent methomyl WP attracted *B. dorsalis* for 13 days. In an 11-day long experiment, one dish of guava fruit (200 g) attracted 25.4 insects (females 13.2 and males 12.2), and one ME board attracted 13.2 females. Suggestions were made for the combination of intermediate and long-term control measures to suppress *B. dorsalis* populations (TienDing *et al*., 1996).

Studies conducted by Singh (1997) at Pantnagar, Uttar Pradesh, India, indicated that *B. dorsalis* damage was reduced to 4.6 per cent by harvesting mango var. Dashehari fruits at physiological maturity, compared with 10 per cent in fully ripe dropped fruits. Damage was similarly reduced from 8 to 4 per cent in var. Bombay Green. Methyl eugenol (0.2%) was used as bait in 4 traps/acre for 18 weeks (2nd April to 30th July) resulted in a reduction in damage of 71.11 per cent in physiologically mature fruits (var. Dashehari) and 71.15 per cent in damage of fully ripe dropped fruits. The largest trap catches of 233 males/week occurred between 18 June and 25 June. Adult emergence was zero when fully mature larvae pupated at a soil depth of 30 cm, followed by 20, 65, 45 and 30 per cent emergence at 20, 10, 5 and 0 cm depths, respectively, indicating the suitability of a 30 cm depth for burying the damaged fruit. In trials of bait traps, mango juice (5%) was the most effective bait in reducing damage to fruits (36.6% in physiologically mature and 17% in dropped fruits). Two high-volume sprays of deltamethrin (0.002%) gave an 83.3 per cent reduction in the damage of physiologically mature and 78.80 per cent in dropped fruits. This was on a par with fenvalerate (0.015%). The only parasitoid recorded was *Biosteres dacusii*.

The attraction of the melon fly, *B. cucurbitae* (Coq.) (Diptera: Tephritidae) to soybean hydrolysate, fishmeal, beef extract, banana/grapes, bread and dog biscuit was evaluated in snakegourd (*Trichosanthes anguina* L.) gardens during 2000-2001. Vinegar and beer were added as the 'bait components' to the above 'base baits' to enhance their attractiveness. Edible oils, glycerine and petroleum jelly were tested as the 'controlled releasers' to sustain the attractiveness. The results indicated that banana and soybean hydrolysate were 85-95 per cent more attractive to adult *B. cucurbitae* than fishmeal, beef extract, bread and dog biscuit. Among the fruit pulps, grapes and banana appeared to be more attractive than pineapple. The attractiveness of baits with palm oil lasted longer (up to 5 days) than that of baits without any controlled releaser (2-3 days). Grapes + beer + palm oil was found to be 37 per cent more attractive than the other admixtures. The fruit flies were attracted towards the baits more intensively between 06.00 and 08.00 h and between 16.00 and 18.00 h (Bharathi *et al.*, 2004).

The attractiveness of three proteinaceous substances (protein hydrolysate, Nu-lure and PIB-7) to *B. dorsalis* was investigated in screen house and field tests in Taiwan. Protein hydrolysate was the most effective bait, attracting 45.4 per cent of adult females and 35.6 per cent of males. Both sexes showed a strong behavioural reaction and were attracted to PIB-7. When the pH values of PIB-7 and Nu-lure were adjusted to 10, over twice as many females were attracted than at the original pH of 4. The most effective concentration of PIB-7 for luring flies was 20 per cent, while Nu-lure and protein hydrolysate were more effective at a concentration of 80 per cent. A synergistic effect was obtained when the improved attractants were mixed with other substances. PIB-7 + wine drugs or brown sugar was more attractive to females than PIB-7 alone (Liu and Chen, 1992).

Steyn *et al.* (1997) monitored fruit fly species in an orchard of guavas in South Africa using trimedlure and beta-caryophyllene in combination with the Sensus trap. Different food attractants (protein hydrolysates, Hymlure, Nasiman, Buminal, Marmite and Bovril) in conjunction with the insecticide trichlorfon were evaluated for baiting *Ceratitis rosa*, the most abundant tephritid in the orchard. The poisoned bait was placed in traps made of plastic bottles. More females than males were attracted, and Buminal was the protein hydrolysate that attracted most adults of that species.

Sunandita *et al.* (2001) reported that the attractant-bait mixture containing boric acid-borax (3:1) as toxicant, protein hydrolysate (4%) as attractant in water, when fed to five-day-old adults of fruit fly, *Bactrocera tau*, kept in rearing cages in the laboratory, caused 40-98.3 per cent mortality after 24 h of exposure with different concentrations (1-12%) of the toxicant. The LC_{50} value was calculated to be 1.95. The bait mixture remained effective upto a week and when sprayed on tomato plants caused phytotoxicity above two per cent concentration of the toxicant, within 24 h.

Labuschagne *et al.* (1995) studied tephritids on mangoes in South Africa. *Ceratitis cosyra* was the dominant fruit fly species attacking mango fruit. Most adults emerging from infested fruit collected at three locations belonged to this species. *C. capitata* occurred in insignificant numbers. These results were confirmed by the numbers of *C. cosyra*, *C. capitata* and *C. rosa* caught in protein hydrolysate traps. The monitoring of fruit flies in commercial orchards is restricted to males of *C. rosa* and *C. capitata*.

Protein baits are widely used in fruit fly management, both in traps for monitoring and as spot sprays for control. A range of studies have used McPhail traps to assess the relative performance of commercial protein hydrolysate baits and various home-made autolysates of brewery waste yeast to develop home-made alternatives to imported hydrolysate bait. In Mauritius, locally made yeast autolysate, produced by a combination of heat autolysis and papain enzyme promoted proteolysis, was tested in field experiments using McPhail traps in mango orchards and in wild growing mango trees at three locations from December 1998 to January 1999. The most abundant fly species were *B. zonata*, *Ceratitis rosa* and *B. cucurbitae*. The locally-made bait was generally as effective when used in McPhail traps as commercially obtained protein hydrolysate bait. However, the locally-made bait did not effectively trap *B. cucurbitae*. Fruit fly catches were greater when protein autolysate was prepared with higher concentrations of papain (2.0 or 4.0 g/litre). In similar experiments in Kenya, conducted in mango orchards in February 2000, certain locally produced autolysate bait formulations out-performed commercial hydrolysate in attracting *C. cosyra* (Gopaul *et al.*, 2000).

Experiments conducted in Seychelles for the comparative assessment of lure and bait traps for the monitoring and control of *C. capitata*, and of soaked-wood killer blocks for the control of *C. capitata*. Dual-attractant traps containing both lure and bait caught fewer males than those with lure alone, and fewer females than those with bait alone. Dilute baits (both commercial protein hydrolysate and locally made autolysed brewer's yeast) caught more fruit flies than concentrated commercial bait, but also more other flies such as muscids. A relationship between bait concentration and catch was not established, but in general weaker solutions performed no worse than stronger. When used as blocks soaked with either bait or lure attractants to attract and kill flies, coconut husk caught more flies than plywood, coconut shell and coconut trunk. There was no clear difference between commercial protein hydrolysate bait and brewers yeast autolysate bait in soaked blocks for attracting and killing flies (Stravens *et al.*, 2000).

The highest number of mango fruit flies was attracted to the standard bait followed by the locally prepared protein bait SLP-1 (1:14). Field investigations with a bitter gourd crop [*Momordica charantia*] indicated that locally produced baits SLP-1 (1:6) and SLP-6 (1:14) were more or equally effective as fruit fly lure for attracting cucurbit fruit flies and reducing fruit damage (Ekanayake and Bandara, 2003).

Ros et al., 2000 conducted a field experiment in a custard apple (*Aaaona cherimola* cv. Fino del Jete) orchard, in Granada, Spain, during 1997, to evaluate the use of mass trapping technique for the control of the Mediterranean fruit fly, *C. capitata*. The treatments comprised (i) nine sprays of Buminal [protein hydrolysates] (0.8%) and malathion (0.6%) and (ii) trapping (Tephry traps) with baits of ammonium acetate, putrescine, trimethylamine or protein hydrolysate (Nulure, 9%) as components. In the plots where traps were more effective, puncture damages were five times less. The results of the experiment were considered positive as the damages were reduced to minimum levels (0.85 of the total crop). If bait sprays were not effective, only a mass trapping technique would be effective in the control of the Mediterranean fruit fly in the orchards.

Stonehouse *et al.* (2005) reported the Bait Application Technique (BAT) to control orchard fruit fly with spray liquid of insecticide (0.1%) and jaggery (10%) or pulped ripe banana (10%) in water. It was applied in spots of 40 ml at the rate of 200 spots/ha (8 l/ha) to the undersides of leaves about 1.5 m above the ground and applied with sprayer or with a fine brush to coat leaf surfaces smoothly.

BAT mixture may be of either jaggery, or banana, or a mixture of both; if fresh fruit are cheaply and readily available, these may be added to the pulp mixture, to control orchard fruit fly (Jhala *et al.*, 2005).

2.2.3 Sticky traps

Robacker and Heath (2001) made a sticky trap for fruit flies from fruit fly adhesive paper (FFAP) covered with a plastic mesh of size 1.5x1.5 or 2.2x2.2 cm. It was as effective as Pherocon AM traps in capturing Mexican fruit flies (*Anastrepha ludens*). FFAP traps without mesh, captured three times more flies than the best traps with mesh. However, mesh eliminates many problems associated FFAP traps. The mesh-covered traps are simple, compact, easy to pack, and do not capture birds or leave residue on the users' hands.

Weldon (2003) conducted a study at the University of Western Sydney, New South Wales, Australia to examine the effectiveness of a simple, unbaited sticky trap in monitoring the dispersal of irradiated *B. tryoni*. The unbaited sticky trap catches of irradiated *B. tryoni* were 12 per cent of those of pot-type traps baited with cue-lure. Sticky traps painted with daylight fluorescent yellow or green were equally effective but were no better than unpainted (control) sticky traps for capturing *B. tryoni*. No association was identified between recaptures in sticky traps and host status of the tree in which the trap was placed. Sticky traps may be useful for detecting the location of emergence foci of endemic flies but were insufficiently sensitive to offer an alternative to current monitoring techniques.

Khater *et al.* (1996) showed that traps containing a 2 per cent solution of diammonium hydrogen phosphate (food) were most effective at high temperatures and low relative humidity. The yellow sticky trap was more effective at attracting adult males than females, and mostly during periods of low temperature and high relative humidity. The attractiveness of pheromone and coloured traps was low during summer. The presence of pheromone traps in olive orchards resulted in higher numbers of males.

The response of males of *B. dorsalis* to colored plastic bucket traps baited with methyl eugenol was determined in a commercial guava orchard in Hawaii. When traps were placed close together on stakes, white and yellow traps caught the largest number of flies, whereas green, red and black caught the fewest. When traps were placed in guava trees, no significant difference in fly captures occurred, although white traps caught the most flies and the same general trend in trap efficiency occurred (Stark and Vargas, 1992).

Chienchung *et al*. (2001) conducted a field study in Taiwan to evaluate the effects of (1) three different marketed protein hydrolysates, (2) different concentrations of the protein hydrolysate, (3) different insecticides added to the lure and (4) different trap densities on the capture of the oriental fruit fly (*B. dorsalis*) on bitter gourd (*Momordica charantia*). The percentage of flies trapped by Chenghong protein hydrolysate was significantly higher than those trapped by Wufeng and Hsingya hydrolysates. The percentage of trapping increased with increasing concentration of the protein hydrolysates. Addition of malathion to the lure improved the capture of female flies; however, this trend was not observed in the lures with fenthion, fenitrothion and trichlorfon. Repellent effects might occur when methomyl was added to the lure. More flies were captured at trap densities of 200 and 300 traps/ha compared with 100 traps/ha, especially during the earlier stage of the treatment. However, there were no significant differences among trap densities. Higher trap density may be useful to capture a large number of the oriental fruit fly quickly when they are entering into the orchard. The female to male ratio in the trap catch decreased as the time of treatment proceeded.

2.2.4 Spathiphyllum as trap plant

Four new attractants to males of *B. dorsalis*, trans-3,4-dimethoxycinnamyl alcohol, trans-3,4-dimethoxycinnamyl acetate, p-methoxybenzyl alcohol and 3,4-dimethoxybenzyl alcohol, and the common attractants eugenol and methyl eugenol, were identified from the headspace of the spadix of *Spathiphyllum cannaefolium* (Chuah *et al*., 1996).

The chemicals from the brown part of the leaves of *Proiphys amboinensis* consist of a mixture of methyl eugenol, 5-allyl-1,2,3-trimethoxybenzene, 3,4,5-trimethoxyacetophenone, aliphatic hydrocarbons and long-chain carboxylic acids.

Males of the *Bactrocera dorsalis* complex (*B. carambolae* and *B. papayae*) are attracted to these parts of the leaves because of the presence of the major component, methyl eugenol. This is the first example of a leaf exhibiting attractant properties in its progress in turning brown (Chuah *et al*., 1997).

Nishida *et al*. (1997) observed that the males of *B. dorsalis*, are strongly attracted to and compulsively feed on *Fagraea berteriana*. A series of phenylpropanoid components, trans-3,4-dimethoxycinnamyl alcohol, its acetate, and trans-3,4-dimethoxycinnamaldehyde were characterized as male attractants.

Kardinan (1999) reported that melaleuca leaves contain oil (1.14%), which contains methyl eugenol (76%) ($C_{12}H_{14}O_2$) which is a fruit fly attractant.

Shelly (2000) reported the males of the oriental fruit fly *B. dorsalis* are attracted to and feed on flowers of the golden shower blossom *Cassia fistula*. Flowers of this plant contain methyl eugenol, the metabolites of which apparently function in the synthesis of male sex pheromone.

2.2.5 Field Sanitation

The effect of field sanitation (twice-weekly removal of ripe fruits from trees and the ground) in suppressing populations of *B. dorsalis* in pawpaw orchards in Hawaii was determined by comparing larval density and percentage infestation in mature green to fully ripe fruits. In addition, the relative density of adults estimated using methyl eugenol-baited traps was compared between orchards with and without sanitation. The orchards without sanitation had an irregular harvesting pattern which resulted in abundant ripe fruits on trees and fallen rotting fruits on the ground. Mature green fruits had no infestation and infestation was observed only in half- and fully-ripe fruits. Larval infestation (density and percentage infested fruit) was lower in half- and fully-ripe fruits collected from the fields where sanitation was practiced. Likewise, the relative density of tephritid adults was lower in the orchards with sanitation (Liquido, 1993).

Alam *et al*. (1999) conducted a study in Bangladesh during October 1997-February 1998 to control fruit fly, *Bactrocera cucurbitae*, infestation in cucumbers (cv. Hiramati). The treatments were mechanical control (hand picking and destroying of infested fruits); cultural control (field sanitation with regular mulching, and collecting and destroying pupae); cover spray with malathion; and an untreated control. The results showed that fruit fly infestation by number (3.01%) and weight (1.96%) was lower with mechanical control than with cultural control methods (4.35 and 2.44%, respectively) and was at par with chemical control (3.18 and 1.64%, respectively). Similar results were obtained when the effect of the treatments on weight reduction per fruit was observed (mechanical control, 29.58%; cultural control, 60.50%; chemical control, 42.44%).

Malavasi (2000) implemented the Carambola Fruit Fly Programme in Guyana, Suriname, French Guiana and State of Amapa, Brazil with the objective of the eradication of *B. carambolae*, the Carambola fruit fly (CFF). CFF is an exotic pest to the Western hemisphere, probably introduced in Suriname in late 1960s or early 1970s. The programme commenced in August 1997 using the male annihilation technique complemented with protein bait sprays, fruit stripping, soil treatment and pruning major host trees. "Bait stations" of fibre blocks impregnated with a methyl eugenol and malathion solution are hung from host trees at 400 to 2000 km^2. Additionally "hot spots" are treated with protein bait-malathion sprays. Additional measures include fruit pruning and host tree removal. CFF surveying uses Jackson and McPhail traps and fruit collection.

B. dorsalis is a serious pest of mangoes in India. Between 1985 and 1996 assessments of the effectiveness of a locally recommended IPM package, in comparison with no control, on a susceptible variety were carried out near Bangalore. The IPM package was applied over 45 days before harvest and comprised of weekly removals of fallen fruit, tri-weekly inter-tree ploughing and raking and fortnightly cover sprays of insecticide thrice. Infestation reductions attributable to the package were between 77 per cent and 100 per cent in different years. Cost-benefit 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).

The effect of a benzyl-1,3-benzodioxole derivative (BBD), J3230 (5-propyl-1-en-3-oxy-6[1-(4-methyoxyphenyl)ethyl]-1,3-benzodioxole) on reproduction of *B. dorsalis* was investigated by exposing late 3rd instars to top soil treated with this chemosterilant. Adult emergence and subsequent egg hatch were significantly reduced. J3230 affected primarily the reproduction of male fruit flies when the mature larvae were exposed to treated soil. When untreated females were mated with males that had emerged from treated soil, the subsequent egg hatch was decreased. This decrease was retained longer with increasing J3230 concentrations. The number of spermatozoa in spermathecae of females mated with males that had emerged from treated soil was significantly reduced. Histological sections further showed aberrant flagella and sperm bundles in testes from the treated group. J3230 activity was reduced when the treated soil was incubated at 25, 35, and 45°C for extended periods; however, its activity could be retained in the soil for > 1 mo at 25 and 35 °C. Short-wave length UV light (254 nm) and soil moisture were also found to affect the activity of this chemosterilant (Yawjen *et al.*, 1997).

2.2.6 Parasitoides of fruit flies

Laboratory-reared larvae of *Anastrepha suspensa* in the wandering period of the last instar were released singly on the soil surface in guava (*Psidium guajava*) and carambola (*Averrhoa carambola*) groves in Florida. Crawling, burrowing and interactions with predators on the soil surface before burrowing were observed. Four days after release, pupae were excavated from the soil and returned to the laboratory for rearing. Depth of pupation in all soils ranged from 0 to 27 mm. Four species of ants were observed attacking wandering larvae. Adult emergence of pupae recovered from all groves ranged from 0 to 98 per cent. Larvae of the elaterid *Conoderus* sp. were observed eating pupae in the field. In the laboratory, the dermapteran *Euborellia annulipes* ate wandering larvae and pupae (Hennessey, 1977).

Messing (2003), demonstrated the parasitism potential by *Fopius arisanus* from Asia, which caused over 95 per cent egg mortality of the Oriental fruit fly (*Bactrocera dorsalis*) in guava.

Bautista *et al*. (1998) studied the development of *Biosteres arisanus* development on *Bactrocera dorsalis* in the laboratory at 22-24°C, 60-70% RH and LD 10:14. Life table statistics were generated for cohorts of *B. arisanus* females. Overlap in the emergence of tephritids and parasitoids necessitated a procedure for segregation, preferably before adult eclosion. Rate of parasitism by *B. arisanus* increased with host clutch size reaching a plateau at a ratio of 20:1 host egg to female parasitoid. Duration of the oviposition period influenced the level of host parasitism; host eggs were exposed to parasitoids for 24 h with minimal superparasitism. Females were highly productive within three weeks after emergence, producing 40-70 per cent females in the progeny. Adult males were shorter lived than females by 5 days. Based on a net reproductive rate of >16 daughters/female, a population increase of 10 per cent was predicted each day.

Stark *et al*. (1991) determined the abundance of *B. dorsalis* and associated parasitoids was determined in a commercial guava orchard in Hawaii by canopy fogging and fruit collections during 1988 and 1989. B. dorsalis populations reached a maximum of 2.6 adults/tree in 1988 and 1.4 adults/tree in 1989. Four parasitoid species were recovered from guava tree canopies; *Biosteres arisanus* was the most abundant species, followed by *Diachasmimoprha longicaudata* [*Biosteres longicaudatus*], *Psyttalia incisi* and *Biosteres vandenboschi*, respectively. *B. dorsalis* and the parasitoids recovered from guava canopies exhibited different sex ratios from populations that emerged from fruit samples. The abundance of *B. dorsalis* and its parasitoids was correlated with the number of ripe fruits present in the orchard. Parasitoid abundance was correlated with *B. dorsalis* abundance in 1988. The diversity and abundance of parasitoids estimated from canopy fogging and fruit collections differed.

The braconid wasp, *Diachasmimorpha longicaudatus* [*Biosteres longicaudatus*], an efficient larval parasitoid of the oriental fruit fly, was introduced from Hawaii and has been successfully raised in the laboratory. This wasp will be used as an agent of biological control, and together with the annihilation technique will form an integrated management method (Wenyung *et al.*, 1996).

Materials and Methods

3. MATERIALS AND METHODS

Investigations were undertaken to study the species diversity and population dynamics of mango fruit fly (MFF), *B. dorsalis* and the possible scope of some biorational management strategies against the species at the College of Horticulture Campus, Vellanikkara.

Preliminary studies were carried out on the emergence pattern of the adult flies, their alightment character on the host plants, determination of the optimum height for the trap exposure and possibilities of any trans system of dispersal if any were conducted to optimise the efficiency of monitoring as well as the eco-friendly management of the fruit fly in the mango orchards.

Laboratory Single Killing Point (SKP) experiments were carried out to evaluate the orientation of fruit fly to different food sources.

Sticky lure swab experiments were also conducted to evaluate the efficiency of different lure for trapping in the monitoring and management of MFF in mango orchard.

Based on preliminary investigations, three field experiments were finally conducted in mango orchard to evaluate selected biorational approaches in the management of MFF.

3.1 POPULATION DYNAMICS OF FRUIT FLIES IN DIFFERENT MANGO ECOSYSTEMS

Studies on population dynamics of fruit flies were carried out in and around of the College of Horticulture Campus, Vellanikkara during August 2005 to July 2006. Males responding Para pheromone methyl eugenol (ME) traps were installed at three locations viz. College orchard, Vellanikkara (Typical fruit orchard consisting of mango, guava, sapota, fig, lovi lovi etc. serving as alternate host for the MFF); Agricultural Research Station (ARS), Mannuthy (A typical mango orchard adjoining to a rice ecosystem) and National Bureau of Plant Genetic Resources (NBPGR), Vellanikkara (a small scale mango varietal cultivation plot interspersed with multitude of germplasm of a variety of plants including host and non host types.

The fruit fly trap was fabricated using plastic pearl pet water bottle of one litre capacity (Plate 2). On the side walls of the bottle, three window cut openings (3 cm x 2 m) were made for the entry of fruit flies. The plywood dispenser blocks of size (5 x 5 x 1.2 cm) were prepared by soaking the para pheromone mixture was suspended at the centre of the bottle trap using a twine. The population of MFF and other fruit flies attracted and killed in methyl eugenol trap was monitored weekly.

The para pheromone wood dispenser soakates was prepared by soaking plywood blocks in a mixture solution of ethanol (60%): methyl eugenol (100 %): malathion 50EC (6:4:1 v:v:v) in an air tight container for seven days. The methyl eugenol traps were fixed at a height of 2 m above ground level (standardized as per 3.2) using a strong twine. The twine was smeared with grease to prevent ants from reaching the trap. The bottom part of the bottle was cut opened and the cut end was inserted at the cut surface in the reverse position so that it could be used as an opening cap and also which would drain any moisture collected with in. Based on the previous experimentation it was found that such pheromone dispenser soakate perform efficiently for more than two months and hence refreshed at bimonthly intervals to maintain the trapping efficacy. Pre labeled/dated plastic covers were been attached to the bottom of the ME traps were collected at weekly intervals along with the trapped fruit flies. The total number of fruit flies trapped, their species composition and sex were recorded from three locations during the study period.

Species diversity of the fruit flies responding to ME traps were recorded in the College orchard, at Vellanikkara. The trap catch data was correlated with weather parameters viz., maximum and minimum temperature, relative humidity, rainfall and wind speed recorded at Vellanikkara (latitude 10°31', longitude 76°13', height above MSL = 40 m).

Plate 2. Fruit fly bottle trap with Methyl eugenol plywood soakate

3.1.1 Population dynamics of fruit flies in different fruit crops

Standardized methyl eugenol traps were tied at a height of 2 m above ground level using a strong twine on different fruit plants viz., sapota, lovi lovi, citrus, fig, guava, carambola and jack for monitoring the FF population and their species variations.

At weekly intervals, the trapped flies were collected and observed for the total number of fruit flies entrapped in the ME bottle traps during August 2005 to July 2006.

3.1.2 Population parameters of fruit flies

The population parameters of fruit fly viz., species richness and species diversity were calculated as described by Magurran (1988).

1. Species richness (S) = Total number of species present in the community
2. Species diversity

a) Simpson - Yule Diversity Index (D)

$$D = 1 \quad \sum_{i=1}^{s} pi^2 \qquad \text{(Range = 1 to S)}$$

where, S = Total number of species present in the community
Pi = Proportion of individuals belonging to the i^{th} species

b) Shannon-Weaver Diversity Index (H)

$$H = -\sum_{i=1}^{s} pi \; \text{In}\; pi \qquad \text{(Range = 0 to InS)}$$

where, S = Total number of species present in the community
Pi = Proportion of individuals belonging to the i^{th} species
In = Natural log

c) Shannon - Weaver Eveness Index (E)

$$E = H / \ln S \quad \text{(Range = 0 to 1)}$$

where, H = Shannon-Weaver Diversity Index

S = Total number of species present in the community

In = Natural log

d) Berger - Parker Dominance Index (d)

$$d = N_{max} / N_T \quad \text{(Range = 0 to 1)}$$

where, Nmax = Total number of individuals in the largest species

N_T = Total number of individuals in all species present in the community

3.1.3 Determination of sex ratio and sex factor relationship in *B. dorsalis*

Studies were carried out to determine the sex ratio and sex factor relationship in MFF during the fruit bearing season in 2006 at different stages of fruit development of mango, guava, bread fruit, rose apple and fig. From each fruit crop, ten infested fruits were collected at random and replicated thrice, during the season. The infested fruits were brought to the laboratory and the adult flies were reared out. The fruits were kept in glass troughs (30 cm x 15 cm) containing a layer of clean moist sand of 5 cm thickness for pupation (Plate 3). The fruits were kept in aluminium foil coated paper plates to avoid direct contact with sand. The trough was then covered with muslin cloth and tied tightly with rubber band. It was regularly examined for pupation and the pupae were collected and transferred to the adult rearing cages of size 30 x 30 x 30 cm. The emerging adults were fed with 10 per cent honey solution, soaked in sponge piece and were kept in a petri dish. These emerging adults were utilized for the sex ratio analysis.

Five pairs of fruit flies each were transferred into 500 ml PET jars (12 cm x 8 cm), in three replication. Each replicate was provided with a piece of banana (cv. Robusta) fruit. as oviposition medium (Plate 4). Ten per cent honey solution soaked in cotton pad was provided for feeding the adult fruit flies. The flies were allowed to oviposit for 24 hours and the banana fruit pieces were removed after oviposition and observed for ovipositional puncture marks and presence of eggs if any.

The eggs were allowed for hatching in banana itself and two days old maggots were transferred to different fruits kept in glass trough with moist sand at the bottom in each replicate. Pupae were collected periodically by checking and filtering the sand. The collected pupae were counted and transferred to the emergence cages for adult eclosion. The emerged adults were sexed, counted and confirmed the species (Plate 5). The sex ratio and sex factor relationships were also calculated using the formulae viz.,

$$\text{Sex ratio} = \frac{\text{No. of female flies}}{\text{No. of male flies}}$$

$$\text{Sex factor} = \frac{\text{No. of female flies}}{\text{Total number of flies}}$$

The sex ratio and sex factor of *B. dorsalis* in different fruits and seasons were subjected to ratio analysis and the significance was tested by chi-square values.

3.1.4 Correlation of fruit fly catches with weather parameters

The trap catches of fruit flies over 12 months period were correlated with the weather parameters with respect to the corresponding standard weeks and partial correlation coefficients were calculated as per Snedecor and Cochran (1967).

3.2 HEIGHT DETERMINATION OF METHYL EUGENOL TRAPS IN MANGO TREES AGAINST FRUIT FLIES

Determination of optimum height for exposing the ME traps in mango during rainy (June and July, 2006) and non rainy (November and December, 2006) periods were done in the mango orchard of College of Horticulture, Vellanikkara, Thrissur.

ME traps were hanged on the mango trees using strong twine at four different heights viz. ground level, 2 m, 4 m and 6 m, in both rainy and non rainy days (Plate 6). The twine was smeared with grease to prevent ants from stealing the fly

Plate 3. Fruit fly with infested mango fruits under rearing

Plate 4. *Bactrocera dorsalis* female fly ovipositing on banana fruit rind

Plate 5. Adult flies of *Bactrocera dorsalis* under rearing cage

Plate 6. ME bottle traps at different heights on mango tree

catches. It was replicated thrice to validate the results statistically. At weekly intervals, the trapped flies were counted and analysed for the optimum height exposure of the ME traps and the FF catches.

3.2.1 Determination of trapping height and orientation of MFF to sticky lure swabbing techniques in different fruit crops against fruit flies

Evaluation of optimum height and MFF directional orientation on the tree trunks by using sticky lure swabbing material was undertaken in mango, bread fruit and sapota during February 2007.

Swabbing materials were prepared by constituting a gelatin based formulation out of the attractants and toxicants and were applied on mango, bread fruit, sapota at selected tree trunk at five height levels such as ground level, 0.5 m, 1 m, 1.5 m, 2 m and 2.5 m and in all the four directions i.e., north, south, east and west. Swab was applied on the selected tree trunk at the different heights and in all directions by using a 10 x 10 cm square cut template. Swabs were replicated thrice on the tree trunks with approximately the same features and conditions.

Swab slurry preparation:

One ml of ME concentrate and 20 g of banana pulp were dispersed in 100 ml of water by strong agitation to prepare the slurry. Malathion 50 EC (0.1 ml) was added into the slurry and mixed it. Finally it was added with gelatin (20 g) as the sticky material and thoroughly mixed by using a glass rod and kept for 10 minutes. Thus the slurry concentrate was made for swabbing on the tree trunk with a hand brush.

3.3 CIRCADIAN RHYTHM OF MFF ATTRACTION ON THE *SPATHIPHYLLUM* SPADIX (PEACE LILY) AS A TRAP PLANT

The peace lily, *Spathiphyllum cannaefolium* called as "trap plant" for MFF were evaluated for its optimum time of attraction between morning 6 am (dawn) to evening 6 pm (dusk).

Twelve one year old tissue cultured plants were planted within the interspace of four mango trees (Plate 7). The mean number of suckers produced by *Spathiphyllum* plant was four and the frequency of flowering by a plant was one at biweekly intervals. The number of flies attracted to a newly emerged spadix till senescence were observed from 6 am to 6 pm at hourly intervals and the maximum catch per hour was determined for the removal trapping.

3.3.1 Removal of fruit flies from Spathiphyllum spadix by "removal trapping"

The fruit flies were removed from the spadix at its peak time at 8 am by removal trapping method using polythene covers (45 cm x 30 cm size) and this catch was counted and correlated with the fruit damage.

3.4 LOCATION OF THE HIDING PLACE OF MFF AT LEAF FLUSHING AND FRUIT MATURITY TIME

The identification of hiding place on mango trees is very important for easy management of fruit flies. Ten mango trees were selected and visually subjected to close scrutiny at different heights on different parts of the tree during both leaf flushing and fruit bearing times.

During leaf flushing time, the observations made were on the following plant parts.

1. Main trunk
2. Primary branches
3. Secondary branches
4. Tertiary branches
5. Leaves (upper side and lower side)
   a) Lower leaves
   b) Middle leaves
   c) Top leaves

In fruiting time, the observations were made on the following plant parts

1. Main trunk

Plate 7. ***Spathiphyllum*** **as trap plants for MFF in mango orchard**

2. Primary branches
3. Secondary branches
4. Tertiary branches
5. Fruits at different heights (Lower, middle and top levels).
   a) Proximal end
   b) Middle part
   c) Distal end

3.5 SPATIAL EMERGENCE PATTERN OF MFF IN MANGO ORCHARDS

A field experiment was carried out to evaluate the spatial emergence pattern of mango fruit flies from the soil basin in mango orchards during the preseason periods.

An emergence trap was designed and fabricated with a square shaped mud pot of size 30 x 30 x 15 cm provided with a hole on its top (Plate 8). Inside of the pot was smeared with sticky grease for entrapping the emerging adult flies. The hole provided in the centre position of the mud pot was sealed with a transparent plastic sheet to permit light entry for the host orientation to fly up and got stuck on the sticky inside of the pot trap.

The variety selected for the study was Prior. From the tree base up to periphery of the canopy shade on the ground, at three radial distances of 1, 2 and 3 m, three mud pots were placed at base of the tree, middle of the canopy spread, and periphery of the canopy of the tree (Plate 9). The position of the mud pot traps were changed weekly around the specified radial circles at random to cover maximum ground area in all the four directions.

The weekly fly emergence counts were taken, based on the flies stuck to inner side of the mud pots as well as the live ones trapped inside. Observations were taken at regular intervals to elucidate the variation in the emergence time from the ground (Plate 10).

Plate 8. Fruit fly Emergence mud pot trap (Type I)

Plate 9. MFF Emergence pot trap in the mango orchard

Plate 10. Fruit fly Emergence mud pot trap (Type II)

3.6 EVALUATION OF THE COMPARISON EFFICACY OF FOOD LURES TO MFF

The comparative performance of food lures on the relative attraction and orientation of the MFF and their distribution under cage experimentation by Single Killing Point (SKP) studies.

Laboratory SKP studies were undertaken in two sets of specially designed choice cages with three compartments each designed and fabricated in the Department of Agrl. Entomology, College of Horticulture, Vellanikkara during March-May 2007 (Plate 11).

Excised mango shoots with the lure treatments were kept in pots in cages under symmetrical features. On the day of treatment application freshly reared out mango fruit fly pupae at 15 numbers each were placed at the centre of the insect cage dividing the two paired comparative treatments representing one replication. Ten per cent honey solution was also kept at the centre as the adult feed. The following comparisons were tried to evaluate the relative attraction and performance of the various food lures for the relative orientation of *B. dorsalis*.

C_1	:	Palayankodan	Vs	Jaggery
C_2	:	Palayankodan	Vs	Robusta
C_3	:	Robusta	Vs	Poovan
C_4	:	Fig	Vs	Roseapple
C_5	:	Guava	Vs	Papaya
C_6	:	Peeled mango	Vs	Unpeeled mango
C_7	:	Var. Prior	Vs	Var. Muvandan
C_8	:	Var. Neelam	Vs	Var. Banganapalli
C_9	:	Var. Alphonsa	Vs	Var. Ollur

Banana fruit slurry after preparation was added with malathion (0.01 ml of 0.2%) and applied over 1 cm^2 area on the mango leaves in the shoot. For solid fruits, it was cut into 2 cm^3 pieces and kept in petridish at the bottom of the cage under mango shoot tips for the fruit fly orientation. The cut faces of fruit cubes were smeared with malathion (0.01 ml of 0.2%) for intoxication (Plate 12).

Observations on the dead flies got distributed on both sides of each of the three paired compartments with the paired treatments constituting three replications were made at 24 h intervals. It was continued till all the flies got killed within 3-5 days.

3.7 HOURLY ATTRACTION OF FRUIT FLIES TO METHYL EUGENOL TRAPS IN SHADED AND UNSHADED AREAS

Studies on the hourly attraction of fruit flies to ME traps under shaded and unshaded conditions were carried out in the College Orchard, Vellanikkara during April 2007. The ME traps were installed at 3 locations within the shaded mango orchard and another three installed outside the mango orchard in typical non cropped areas. The mango fruit flies attracted and got killed within ME traps were monitored at 6 am (dawn) and at 6 pm (dusk) for three days consecutively.

The ME traps were exposed in both the location at a height of 2 m above ground level and secured properly to avoid swinging. The twine was smeared with grease to prevent the ants from devouring the dead fly catch within the bottle traps.

3.8 STUDIES ON THE SPREAD AND DISTRIBUTION OF MFF

In order to search out the possibility of the possible spread and distribution aspects of the MFF or the prevalence and spread of the MFF over time and distance across the zones from dry arid tracts of Tamil Nadu to humid tropical areas of Trichur through the interzonal semi dry areas of Muthalamada and Kamprathuchella covering a distance of 80 km. Ten locations at an interval distance of approximately 5-10 km were selected and installed with three standard ME traps each per site for continuous monitoring. The MFF catch was taken at weekly intervals from the mango pre-season to post season period (standard weeks from 48^{th} 2006 to 24^{th} 2007). The locations were,

Plate 11. Fruit fly lure testing and evaluation cage for Single killing point (SKP) experimentation

Plate 12. Fruit cubes as food lures against MFF before SKP experimentation

Places	Anthropological areas	Type of Agroecosystem
1) Pulikken market	Thrissur town limit	Homestead mangoes and urban
2) Mannuthy	Town suburb	Pure mango ecosystem
3) Vellanikkara	Orchard areas	Mixed fruits ecosystem
4) Pattikadu	Mixed farm areas	Rubber based plantation ecosystem
5) Vadakenchery	Mixed farm areas	Rubber + Natural ecosystem
6) Nenmara	Mixed farm areas	Rubber + rice + coconut ecosystem
7) Kollengodu	Mango orchard areas	Melons + rice + coconut ecosystem
8) Muthalamada	Mango orchard areas	Rice + Coconut plantation ecosystem
9) Narryparachella	Mango orchard areas	Pure mango orchard ecosystem
10) Sadayanpallam	Mango orchard areas	Coconut + Mango ecosystem

The bottom of the ME trap PET bottle was cut opened and polythene cover was fitted for easy removal and counting of the dead fruit flies. At weekly intervals, the trapped and dead flies were removed for observation and their total number was recorded.

3.9 SUSCEPTIBILITY OF DIFFERENT MANGO VARIETIES TO MFF INFESTATION

Preliminary studies on the susceptibility of mango varieties to fruit fly infestation were carried out during the season based on the oviposition punctures on the fruit rind. Batches of thirty fruits each were selected at random from the harvested lot per variety and the per cent infestation was determined and the relative susceptibility of the varieties worked out.

3.9.1 Per cent infestation of different fruit varieties against fruit fly infestation

Preliminary studies on the per cent infestation on different fruit crops to fruit fly infestation were carried out during the season based on the oviposition punctures on the fruit rind. The fruits were randomly selected from the harvested lots and visually observed for the ovipuncture marks and afterwards were kept for rearing out the adult flies for the species identification. The per cent FF infestation were determined for the different growth stages of mango, sapota, guava, fig, rose apple, banana, breadfruit, jamun, caram bola, papaya, lovi lovi, west Indian cherry, kudampuli, bilimbi, karonda and passion fruit. The percent infestation was calculated using the formula,

$$\text{Per cent infestation} = \frac{\text{No. of fruits infested with FF ovipunctures}}{\text{Total no. of fruits collected for observation}} \times 100$$

3.10 STICKY LURE TRAP TECHNIQUE IN DIFFERENT FRUIT ECOSYSTEM (MANGO AND SAPOTA)

Yellow sticky lure trap experiments were conducted in mango and sapota orchards, College of Horticulture campus, Vellanikkara, during March to April 2006 to evaluate the efficiency of methyl eugenol mediated food lures with yellow colour perception against MFF.

Three sizes of yellow sticky fibre boards were prepared and each type installed in the field at vertical and horizontal position at 10 m intervals. The sticky yellow fibre boards were swabbed with the attractant mixture i.e., methyl eugenol - banana slurry refreshed at weekly intervals. Three replicates were maintained to optimize the catch data.

The yellow sticky board sizes tried were,

1) 30 x 20 cm vertical
   30 x 20 cm horizontal
2) 30 x 10 cm vertical
   30 x 10 cm horizontal
3) 20 x 10 cm size yellow card

Preparation of methyl eugenol - banana slurry

One ml of methyl eugenol and 20 g of banana pulp was macerated and made upto 100 ml by adding water. Malathion (0.1 ml of 0.1%) was added into the solution and mixed well. Finally 20 g of gelatin was added as the sticky base into the mixture and thoroughly mixed by using a glass rod. It was kept for 10 minutes for drying to get it as a slurry for easy pasting on the yellow fibre boards.

Counts were taken continuously at weekly intervals on the number of fruit flies stuck onto the yellow fibre board and the efficiency was evaluated.

3.11 SWABBING TECHNIQUE IN MANGO ORCHARDS AGAINST MFF

Sticky lure swab experiments were conducted in the mango orchard of College of Horticulture, Vellanikkara, to determine the efficacy of different food lures/attractants against MFF during rainy and non rainy periods.

A special paste formulation was developed for swabbing the lures on to the stem of the mango trees for entrapping both the sexes of MFF. Swabbing was done on selected tree trunks at 2 m height from the ground level. The selected tree trunk was covered with a rain guard (Plate 13) one foot below the pasting material to collect fallen dead fruit flies. The rain guard was smeared with grease for protecting dead fruit flies from ants. It was replicated three times.

The following treatments were prepared at 100 ml solution.

1. Methyl Eugenol (1 ml) + Jaggery (20 g)
2. Methyl Eugenol (1 ml) + Banana (20 g)
3. Protein hydrolysate (3%)
4. Protein hydrolysate (3%) + Methyl Eugenol (1 ml)
5. Jaggery (20 g)
6. Banana (20 g) + Jaggery (20 g)
7. Mango pulp (20 g)

Plate 13. Sticky lure swab trap on mango tree with the modified rain guard material

8. Ocimum leaves (25 g)
9. Methyl eugenol (1 ml)
10. Banana (20 g)
11. Control (with gel paste alone)

Counts were taken at weekly intervals, based on the fruit fly species stuck onto swabbed tree trunk and dead flies fallen within rain guard.

Swab slurry preparation: Predetermined quantity of lure/lure mixture was made up to 100 ml by adding water to prepare the slurry. It was then added with 0.1 ml of 0.1 per cent malathion for intoxication. Finally 20 g of gelatin was added as the sticky base into the mixture and thoroughly mixed by using a glass rod to enhance the sticky property to entrap the flies. It was kept for 10 minutes to become a thick slurry and used for swabbing on the tree trunk with a brush.

3.11.1 Determination of the efficacy of different attractants to fruit flies

Efficacy of different lures / attractants against different MFF species was evaluated in the sticky lure swab experiment in non rainy periods. The fruit flies which were attracted to the swab lures on the mango trees were collected and the species were identified by using standard taxonomic keys.

The treatments were as follows:

1. Methyl eugenol (1 ml)
2. Banana slurry (20 g)
3. Jaggery solution (20 g)
4. Banana (20 g) + Jaggery (20 g)
5. Ocimum (25 g)
6. Mango pulp (20 g)

3.12 FIELD EVALUATION OF SELECTED BIORATIONAL APPROACHES IN THE MANAGEMENT OF MFF IN MANGO ORCHARD.

Three field experiments were conducted to evaluate the efficacy of selected biorational approaches that were proved successful in the initial field trials and cage experiments.

3.12.1 Field experiment I

An experiment was conducted in the College orchard at Vellanikkara during December 2005 to May 2006 on mango variety Prior. The experiment was laid out in a Randomized Block Design, with nine treatments replicated thrice. Four mango trees each with uniform features of flowering nature were selected as one treatment. The treatments of the experiment consisted of the following lures and attractants for entrapping the MFF and disorientating their behaviour under field conditions.

1. Methyl eugenol bottle trap
2. Protein hydrolysate bait spray (3%)
3. Banana (20 g) + jaggery trap (20 g)
4. Yeast autolysate bait trap (200 ml)
5. Fish meal (5 g) + pineapple trap (20 g)
6. Ocimum trap (25 g)
7. Mango powder (25 g)
8. Malathion (0.1%)
9. Control (water spray)

Preparation and application of the lure materials

1) ME Trap

The trap was installed using the standard ply wood dispenser soakate in ME mixture and kept in a pearl pet bottle of one litre capacity with three windows cut as described in the section 3.1. The ply wood dispensers were replaced in every four weeks with fresh ones.

2) Protein hydrolysate bait spray

A mixture of 3 per cent protein hydrolysate (200 ml) and 0.1 per cent malathion was prepared in 200 ml of water and squirted as bait sprays on the underside of leaves at the rate of 4 spots of 5 ml each per tree. The bait sprays were repeated at weekly intervals till harvest.

3) Banana + jaggery trap

Banana and jaggery mixture was prepared by blending 20 g of ripened *Palayankodan* variety of banana fruit pieces and 20 g of jaggery with 0.1 per cent of malathion in one litre of water. This was kept exposed @ 50 ml mixture in coconut shells (2 traps per treatment) in the field and was replenished every week till harvest.

4) Yeast autolysate bait trap

The yeast autolysate was prepared using the methodology described by Lioyd and Drew (1997).

Bakers yeast (*Saccharomyces cerevisiae*) obtained from local market was utilized for the study. Yeast granules (20 g) were finely powdered using a waring blender and made into slurry by adding 30 ml of water. The volume was made up to 100 ml, mixed thoroughly and taken in a 250 ml beaker. The yeast slurry was pasteurized at 70°C for 16 hrs, by stirring occasionally to prevent settlement, and then left to cool for overnight. The remaining volume was made up to 100 ml again and 0.5 g papain was added to autolyse the protein in the yeast. The slurry was kept at room temperature for 24 hrs. The autolysed yeast was again heated at 70°C for 16 hrs, stirring occasionally, and left to cool overnight. The volume was made up to 100 ml and allowed to settle for 1 hr. The clear upper liquid was pipetted out, leaving behind the sediment. Potassium sorbate crystal was added at the rate of 0.2 g/l, as a preservative. The resultant suspension was treated as equivalent to the commercial protein hydrylysate. A mixture of 10 per cent yeast autolysate and 0.1 per cent malathion was delivered in each pet bottle traps at the rate of 200 ml. Every week the mixture was replaced with fresh ones.

5) Fish meal + pineapple trap

A mixture of 5 g of fish meal, 20 g of pineapple pieces and 0.1 ml malathion was prepared and it was exposed as trap in the field in coconut shells @ one per treatment and weekly refreshed till harvest.

6) Ocimum trap

25 g of finely cut leaves of ocimum was mixed with 0.1 ml of malathion. It was kept exposed in coconut shells (2 traps/treatment) and was replaced at weekly intervals and continued till harvest.

7) Mango powder

A mixture of 25 g of mango powder in 25 ml of water and 0.1 ml malathion was prepared and were used as traps in coconut shells (2 traps/treatment) and continued till harvest refreshing weekly.

8) Malathion

Three rounds of malathion (0.1%) water spray under high volume application was done as cover spray on the mango trees at the stages of flowering, marble stage of the fruit and lemon stage of fruit development.

9) Water spray

Three rounds of water spray under high volume application was done as cover spray on the mango trees at the stages of flowering, marble stage of the fruit and lemon stage of fruit development.

During each harvest after the last treatment application thirty fruits each were selected at random from the total harvest pool per treatment and the per cent infestation of fruit damaged was estimated and subjected to statistical analysis. The per cent fruit damage was calculated based on the oviposition puntures on the fruit rind (Plate 14).

3.12.2 Field Experiment II

The second field experiment was also conducted in the college orchard at Vellanikkara during December 2005 to May 2006 on mango variety Alphonso. The experiment was laid out in a Randomised block design with nine treatments replicated three times, with four mango trees under each treatment.

The per cent damage was calculated based on the oviposition puntures on the fruit rind (Plate 15). Thirty fruits each were selected at random from the harvested lot per treatment and the per cent infestation noted from the pooled total.

The same set of treatments used in field experiment I was repeated in the field experiment II with the variety Alphonso.

3.12.3 Field experiment III

This experiment was conducted in the college orchard at Vellanikkara during December 2006 to May 2007 in mango variety Prior. The experiment was laid out in a Randomized block design, with nine treatments replicated three times and each treatment having four mango trees. The treatments of the experiment were,

1. ME Trap
2. Banana (20 g) + Jaggery trap (20 g)
3. Yeast autolysate bait trap (200 ml)
4. ME (1 ml) + Banana (20 g) swab trap
5. ME (1 ml) + Banana (20 g) bait spray
6. Fallen fruit sanitation
7. Soil treatment (0.1%)
8. Malathion (0.1%)
9. Control (water spray)

Plate 14. Fresh ovipunctures by *Bactrocera dorsalis* flies on mango var. Prior

Plate 15. Fresh ovipunctures by *Bactrocera dorsalis* flies on mango var. Alphonso

Preparation and application of the lure materials

1) ME Trap

The trap was prepared using standard ply wood block dispenser soakate kept in a pearl pet bottle one litre capacity with three window cuts as described in the section 3.1. The ply wood dispensers were replaced after every four weeks with fresh ones till harvest.

2) Banana + Jaggery trap

Banana, jaggery mixture was prepared by blending 20 g of *Palayankodan* banana fruit pieces and 20 g of jaggery with 0.1 ml malathion. This was exposed in coconut shell trap @ 2 per treatment in the field and was replenished every week till harvest.

3) Yeast autolysate bait trap

The yeast autolysate was prepared as described in the section (3.12.1) and applied at the rate of 200 ml/trap/treatment and was replaced weekly once till harvest.

4) ME + Banana swab trap

A mixture of 1 ml methyl eugenol and 20 g of *Palayankodan* banana ground and made up to 100 ml by adding water, 0.1 ml of malathion as the killing agent and 20 g of gelatin as sticky material were added and thoroughly mixed by using a glass rod. This was kept for 10 minutes till it became slurry. The paste was then applied using a brush to a width of one foot around tree trunk at 2 m above the ground level to act as a sticky lure swab for the MFF. It was repeated at weekly intervals and continued till harvest.

5) ME + Banana bait spray

A mixture of 1 ml of methyl eugenol and 20 g of *Palayankodan* banana pieces were ground and made up to 100 ml by using water and intoxicated with 0.1 ml of malathion. The bait mixture spray was squirted using a hand sprayer as spots onto the under side of leaves at the rate of 4 spots/tree and 5 ml / spot. It was repeated at weekly intervals till the harvest.

6) Fallen fruit sanitation

The fallen fruits were regularly collected and destroyed at weekly intervals, starting from the marble fruit stage onwards till harvest.

7) Soil cover spray

Malathion (0.1%) was applied as soil cover spray around the tree basin covering entire shade area of the mango tree using high volume sprayer and repeated thrice till harvest during marble stage, lemon stage and fruit maturity time.

8) Malathion foliage cover spray

Malathion (0.1%) as a cover spray was given on the mango trees in three times during flowering, marble stage and lemon stage of the fruit.

9) Water spray

Water as a cover spray was given on the mango trees in three times during flowering, marble stage and lemon stage of the fruit.

The per cent damage was calculated based on the oviposition puntures on the fruit rind. Thirty fruits each were selected at random from the harvested lot per treatment and the per cent infestation noted from the pooled total.

3.13 MANAGEMENT OF POST HARVEST LOSS IN MANGO FRUITS DUE TO LATENT DAMAGE BY FRUIT FLY OVIPOSITION INJURY

A post harvest hot water dipping technique was undertaken in mango fruits variety Alphonso against fruit fly damage due to latent oviposition injury before storage during ripening. It was done in the Department of Agrl. Entomology, College of Horticulture, Vellanikkara during May 2007.

Mature mango fruits after harvest were sorted out based on the oviposition marks on the rind as uninfested and infested ones. The infested fruits were subjected to hot water treatment at the standardised temperature of 50°C to 55°C at different exposure combinations of time interval and salt concentrations. The treatments were consisted of the following combinations with:

1) Dipping time periods for 1 minute (T_1), 15 minutes (T_2), 30 minutes (T_3) and 45 minutes (T_4).

2) Salt concentrations of 0.5% (C_1), 1 % (C_2), 2 % (C_3) and 3 % (C_4);

Accordingly the treatment combinations were,

1) T_1C_1, 2) T_1C_2, 3) T_1C_3, 4) T_1C_4, 5) T_2C_1, 6) T_2C_2, 7) T_2C_3, 8) T_2C_4, 9) T_3C_1, 10) T_3C_2, 11) T_3C_3, 12) T_3C_4, 13) T_4C_1, 14) T_4C_2, 15) T_4C_3, 16) T_4C_4.

Approximately 50°C to 55°C was maintained by mixing 6 parts by volume of water with 4.25 parts by volume of boiling water (100°C) at ambient temperature (30-32°C). Then the infested fruits with oviposition marks were dipped at different combinations of salt water concentrations and time intervals as per treatment combinations. Three replicated sets were maintained. After the dip treatments, the fruits were removed, swabbed off the moisture on the fruit and stacked in paper cartons for ripening. After ripening the fruits were cut opened and examined for live and dead egg and maggot stages of MFF. The number of dead or live eggs and maggots as well as the per cent infestation and per cent protection afforded to the fruits were determined and the data subjected to analysis.

3.14 FIELD SURVEY ON THE NATURAL ENEMIES OF *B. dorsalis*

Mango fruits infested with fruit flies were collected from the college orchard at Vellanikkara during two consecutive seasons of 2006 and 2007 and were stored and incubated for emergence of parasitoids from the eggs, maggots and pupae of MFF using a systematic sampling procedure.

The mango orchard with Prior variety was subjected to a systematic sampling by observing 20 trees selected at random. From every two trees one fruit fly infested fruit was randomly collected during the ripening stage at the time of three harvests. Accordingly ten infested fruits were subjected to storage and rearing out the MFF stages along with natural enemy complex if any.

Fruits were immediately brought to the laboratory and placed within glass troughs of size 30 cm x 10 cm containing 5 cm layer of clean, moist sand at the bottom. The fruits were placed on aluminum foil coated paper plates within the troughs to avoid direct contact with sand. Pupae were removed from sand periodically, counted and placed in adult rearing cages and observed for emergence of the parasitoids from the pupae. Per cent infestation was calculated based on the number of pupae recovered and number of parasitoids emerged.

Predators of *B. dorsalis*

Mango orchards in the College of Horticulture, Vellanikkara were surveyed at weekly intervals during the fruiting seasons and observed for the predators of fruit fly.

3.15 STATISTICAL ANALYSIS

Critical Difference values were calculated at 5 per cent probability level and the treatment mean values were compared using Duncan's Multiple Range Test (DMRT) (Duncan, 1951).

Results

4. RESULTS

Investigations on the "Species diversity of the orchard fruit fly complex and the biorational management of the mango fruit fly *Bactrocera dorsalis* (Hendel)" in the mango orchards of College of Horticulture, Vellanikkara and farmers field were conducted during 2005 to 2007. The results of the studies are presented in this chapter.

4.1 POPULATION DYNAMICS OF FRUIT FLIES IN MANGO ORCHARDS

The population of mango fruit fly and other fruit flies responding to the para pheromone, methyl eugenol (4-allyl-1,2-dimethoxy benzene- carboxlate) in PET bottle traps were monitored at weekly intervals from August 2005 to July 2006 (i.e. from 31^{st} standard week of 2005 to 30^{th} standard week of 2006) in three locations of Mannuthy and Vellanikkara regions. The weekly mean catch of fruit flies over 52 standard weeks is furnished in Table 1.

The male fruit flies were trapped throughout the experimental period, with an average catch of 145.2 flies in Mannuthy location, 125.3 in college orchard at Vellanikkara and 86.4 in NBPGR orchard at Vellanikkara. In Agricultural Research Station (ARS) at Mannuthy, the highest trap catch (270.6) was recorded during the second week of March 2006 and the lowest (52.0) during the second week of December 2005. In the college orchard at Vellanikkara also the highest trap catch (248.6) was recorded during the second week of March 2006 and the lowest (32.0) during the first week of November 2005. The same trend was observed in the NBPGR orchard at Vellanikkara with a highest catch of 167.0 nos. during the first week of March 2006 and lowest catch of 21 nos. in the first week of November.

Among the three locations, the maximum catch was observed in ARS, Mannuthy (145.2) and the moderate catch was observed in the other two locations 125.3 and 86.4 flies respectively at Vellanikkara regions (both Horticulture College and NBPGR mango orchards). There was significant difference in trap catches at all the three locations. In all the three locations, four peaks in the population of fruit flies were observed from first week of February 2006 to second week of April 2006.

Table 1. Population dynamics of fruit fly complex in mango orchard systems at three locations in Thrissur during August 2005 to July 2006

Sl. No.	Standard weeks	Fruit fly catch* in the ME traps		
		ARS, Mannuthy	College Orchard, Vellanikkara	NBPGR, Vellanikkara
1	Aug. 2005-31	158.3	137.6	128.0
2	32	142.3	121.0	113.0
3	33	111.6	90.0	77.6
4	34	102.3	82.0	82.0
5	35	111.0	80.0	72.3
6	Sep. 36	87.3	65.6	52.3
7	37	143.3	120.6	111.0
8	38	137.0	117.3	113.6
9	39	133.0	113.3	106.6
10	Oct. 40	92.3	72.0	66.0
11	41	102.3	80.6	70.6
12	42	100.6	80.6	74.0
13	43	105.6	88.3	82.3
14	Nov. 44	50.6	32.0	21.0
15	45	53.3	37.3	28.0
16	46	64.0	46.0	36.0
17	47	71.3	52.0	45.0
18	48	60.6	40.3	32.0
19	Dec. 49	65.6	45.3	36.0
20	50	52.0	32.3	30.6
21	51	54.0	35.6	35.6
22	52	51.3	34.3	30.6
23	Jan. 2006-1	93.6	80.0	71.0
24	2	100.3	83.0	71.6
25	3	144.6	130.0	120.3
26	4	140.3	124.3	100.0
27	Feb. 5	241.6	218.6	93.0
28	6	245.6	226.0	154.6
29	7	201.6	184.0	125.3
30	8	207.6	190.0	130.0
31	Mar. 9	254.0	236.0	167.0
32	10	270.6	248.6	132.3
33	11	192.3	173.0	82.0
34	12	197.3	174.6	84.0
35	13	254.6	235.3	88.3
36	April 14	250.6	230.6	122.6
37	15	164.0	144.3	72.0
38	16	172.3	150.6	115.0

Contd.

Table 1. continued

Sl. No.	Standard weeks	Fruit fly catch* in the ME traps		
		ARS, Mannuthy	College Orchard, Vellanikkara	NBPGR, Vellanikkara
39	17	164.3	142.3	110.3
40	May 18	203.6	182.3	141.6
41	19	206.3	185.6	82.0
42	20	220.6	202.3	135.6
43	21	231.0	209.0	136.6
44	June 22	165.6	145.3	85.6
45	23	171.3	152.3	85.0
46	24	154.0	133.6	72.3
47	25	158.3	136.6	83.6
48	26	131.6	110.0	82.0
49	July 27	136.6	115.3	100.6
50	28	142.3	122.6	75.3
51	29	142.3	124.0	63.6
52	30	143.6	121.6	67.0
	Total	7551.9	6515.7	4494.2
	Mean	145.2	125.3	86.4

* The weekly mean catch from three standard ME traps per location

In all the three locations, moderate catch was recorded during the 31st standard week (August 2005) and there after a gradual decline in the trap catch was observed till the last week of October 2005. This was followed by a sharp decline in the trap catch and the population reached the lowest catch during the entire November and December (2005) months. Consequently the population reached the first peak by February (2006) first week and this was maintained till fourth week of May. The fruit fly catch was at moderate levels during the months of June and July 2006.

4.1.1 Correlation between fruit fly catches and weather parameters

The results on correlations between fruit fly catch (COH, Vellanikkara trap catch) and weather parameters revealed that (Table 2), both the maximum and minimum temperatures showed a significant positive correlation with the fruit fly trap catch. The correlation coefficient values were 0.525 and 0.305 for the maximum and minimum temperatures respectively. The wind speed, rainfall and relative humidity showed non significant correlation with the population.

4.1.2 Population dynamics of fruit flies in different fruit orchards

The population of MFF and other fruit flies responding to ME trap was monitored at weekly intervals from August 2005 to July 2006 (i.e. from 31st standard week of 2005 to 30th standard week of 2006) in sapota, lovi-lovi, citrus, fig, guava, carambola and jack (Table 3 and Fig. 1).

In sapota, the trap catch of fruit flies in the same level throughout the study period with an average catch of 47.6 flies/trap/week. A higher catch of 85 and 82 nos. were recorded during the first week of August 2005 and first week of December 2005 respectively.

The mean weekly trap catch of fruit fly in lovi-lovi was 80.0. Higher catches of fruit flies were recorded during the periods from first week of November 2005 (210.0) to second week of December 2005 (195).

Table 2. Correlation coefficients of fruit fly catch and weather parameters at Vellanikkara

Weather parameters	Partial correlation coefficient
1. Maximum temperature	0.525**
2. Minimum temperature	0.305*
3. Relative humidity	-0.005
4. Wind speed	0.011
5. Rainfall	0.082

** Correlation is significant at the 0.01 level
*   Correlation is significant at the 0.05 level

Table 3. Population dynamics of fruit fly complex in different fruit crop systems at Vellanikkara during August 2005 to July 2006

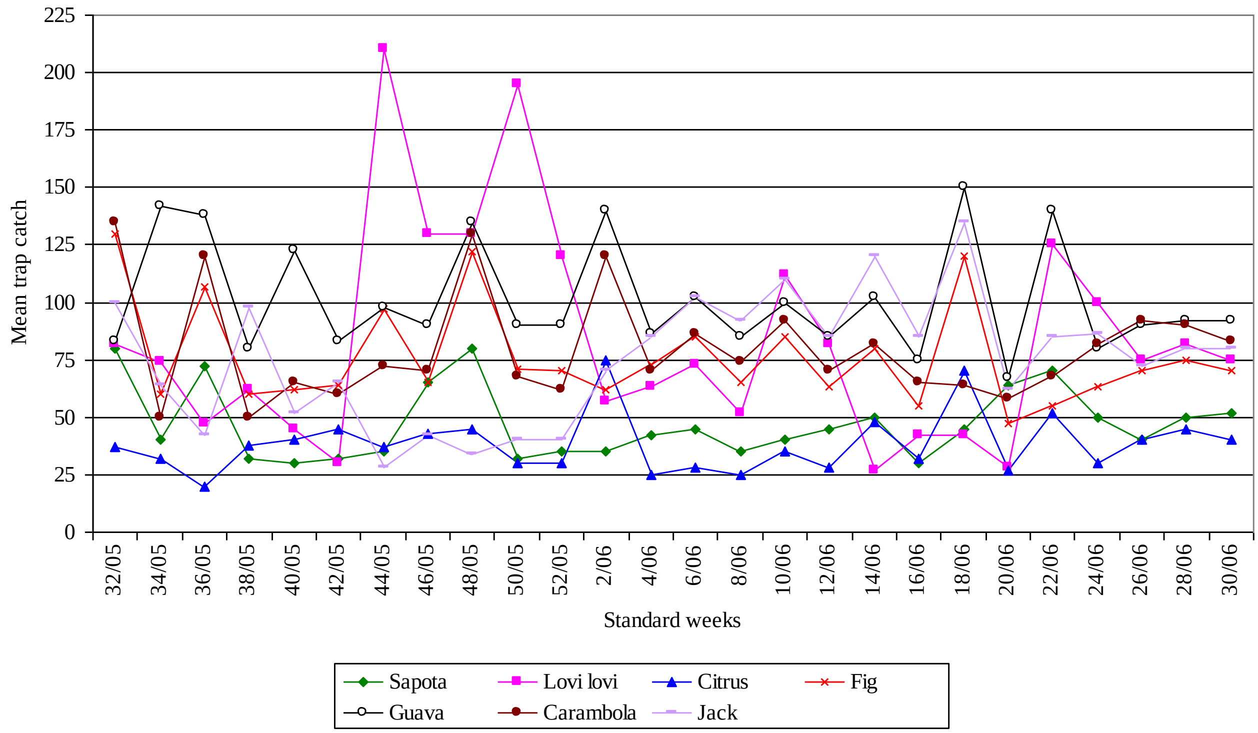
Sl. No.	Standard weeks	Weekly mean fly catch in the ME traps						
		Sapota	Lovi lovi	Citrus	Fig	Guava	Caram-bola	Jack
1	Aug.2005-31	85	80	40	125	80	130	116
2	32	80	82	37	130	83	135	100
3	33	45	70	35	65	148	55	72
4	34	40	74	32	60	142	50	64
5	35	80	50	25	105	140	128	65
6	Sep. 36	72	47	20	107	138	120	42
7	37	35	60	35	62	82	52	102
8	38	32	62	38	60	80	50	98
9	39	30	60	35	58	75	48	95
10	Oct. 40	30	45	40	62	123	65	52
11	41	35	47	43	65	125	75	65
12	42	32	30	45	64	83	60	65
13	43	37	37	42	62	85	62	67
14	Nov. 44	35	210	37	97	98	72	28
15	45	40	205	35	105	100	70	35
16	46	65	130	43	65	90	70	42
17	47	72	132	42	60	86	68	50
18	48	80	130	45	122	135	130	34
19	Dec. 49	82	200	42	127	132	128	35
20	50	32	195	30	71	90	68	40
21	51	38	125	35	72	92	65	42
22	52	35	120	30	70	90	62	40
23	Jan. 2006-1	30	48	73	65	145	125	56
24	2	35	57	75	62	140	120	70
25	3	40	60	20	70	87	68	82
26	4	42	63	25	73	86	70	85
27	Feb. 5	42	70	25	80	96	84	100
28	6	45	73	28	85	102	86	102
29	7	30	50	20	62	82	72	90
30	8	35	52	25	65	85	74	92
31	Mar. 9	35	110	30	83	102	88	102
32	10	40	112	35	85	100	92	110
33	11	42	80	27	60	82	73	82
34	12	45	82	28	63	85	70	85
35	13	55	25	50	83	100	80	125
36	April 14	50	27	48	80	102	82	120
37	15	35	37	30	52	72	63	86
38	16	30	42	32	55	75	65	85

Contd.

Table 3. continued

Sl. No.	Standard weeks	Weekly mean fly catch in the ME traps						
		Sapota	Lovi lovi	Citrus	Fig	Guava	Caram-bola	Jack
39	17	30	35	30	50	70	62	82
40	May 18	45	42	70	120	150	64	135
41	19	40	25	75	110	152	64	132
42	20	64	28	27	47	67	58	62
43	21	65	25	28	52	75	55	65
44	June 22	70	125	52	55	140	68	85
45	23	72	118	47	62	135	67	80
46	24	50	100	30	63	80	82	86
47	25	55	105	35	67	85	86	82
48	26	40	75	40	70	90	92	72
49	July 27	45	70	42	72	95	95	75
50	28	50	82	45	75	92	90	80
51	29	55	80	43	73	90	85	82
52	30	52	75	40	70	92	83	80
	Total	2476	4164	1981	3923	5251	4126	4019
	Mean	47.6	80.1	38.1	75.4	100.9	79.3	77.2

Fig. 1. Population dynamics of fruit fly complex in different fruit crop systems at Vellanikkara during August 2005 to July 2006



In citrus also, fruit fly catches remained somewhat at the same level throughout the study period with an average catch of 38.09. The highest catch of fruit flies (75.0) was recorded in citrus during the second week of May 2006.

The average trap catch of fruit flies in fig was 75.44 and higher catches of fruit flies were recorded during the months of August 2005 (130.0), December 2005 (127.0) and May 2006 (120.0).

The mean weekly trap catch of fruit flies in guava was 100.9. The peaks of fruit fly population were recorded during the third week of August (148.0), last week of November (135.0), first week of January (145.0) and second week of May (152.0).

The average trap catch of fruit flies in carambola was 79.3. Higher catches were observed during the months of August, December and January and moderate catches were observed during other weeks of the study period.

The highest catch of fruit fly in jack was observed in the month of May with an average catch of 77.2 and with lower catches during the following months till November and December.

Among the different fruit crops observed for the relative population levels of fruit fly, the guava had the highest mean catch per week (100.9) followed by lovi-lovi, carambola, jack and fig. The lowest mean trap catch was observed in citrus and sapota.

4.1.3 Correlation between fruit fly catches of different fruit crops and weather parameters

The results on correlations between fruit fly catch (trap catches on different fruit crops) and weather parameters are furnished in Table 4. In sapota, the maximum temperature decreased the fruit fly catch (r = -0.404), whereas, rainfall increased the trap catch (r = 0.387) and the other parameters showed a non significant correlation with the fruit fly population. In lovi-lovi, the maximum and minimum temperatures as well as relative humidity showed a significant positive correlation with the fruit fly

Table 4. Correlation coefficient of fruit fly catches in different host fruits and weather parameters at Vellanikkara

Weather parameters	Partial correlation coefficient						
	Sapota	Lovi Lovi	Citrus	Fig	Guava	Carambola	Jack
1. Maximum temperature	-0.404**	0.323*	-0.088	-0.097	-0.117	-0.190	0.347*
2. Minimum temperature	-0.012	0.620**	0.354*	0.000	0.162	-0.060	0.333*
3. Relative humidity	0.200	0.310*	0.008	0.010	-0.043	-0.147	0.128
4. Wind speed	-0.152	-0.257	0.030	-0.047	0.076	0.201	-0.078
5. Rainfall	0.387**	0.146	-0.041	-0.034	0.003	0.091	0.083

** Correlation is significant at the 0.01 level

* Correlation is significant at the 0.05 level

catch. The correlation coefficient values were 0.323, 0.620 and 0.310 for the maximum temperature, minimum temperature and relative humidity respectively.

In the case of citrus, the minimum temperature increased the fruit fly trapcatch (correlation coefficient value 0.354) and other parameters showed a non significant correlation with the fruit fly population. In jack, both the maximum and minimum temperatures showed a significant positive correlation with the fruit fly trap catch. The correlation coefficient values were 0.347 and 0.333 for the maximum and minimum temperatures respectively and the other parameters viz., relative humidity, wind speed and rainfall showed a non significant correlation with the fruit fly population. In guava, fig and carambola, all the weather parameters showed a non significant correlation with the fruit fly population.

4.1.4 Monthly catch and species diversity of fruit flies in mango orchards at Vellanikkara

The monthly collection of male fruit flies in ME traps at Vellanikkara during the study period is furnished in Table 5.

Four species of fruit flies viz. *B. dorsalis* (Hendel), *B. caryeae* (Kapoor), *B. correcta* (Bezzi) and *B. zonata* (Saunders) (Plates 16 to 20) were identified from the trap catch during the study period with the help of the taxonomists in the Department of Entomology.

The adult males of *B. dorsalis* were trapped throughout the study period, with an average catch of 1436.4 flies/trap/month. The highest trap catch (2674) was recorded during April, 2006 and the lowest (406) during the December, 2005.

In the first week of August 2005, 1148 flies were recorded and there after a gradual decline in the trap catch till October, 2005 (831). After that a sudden decrease in trap catch was observed during the months of November (424) and December (406). Thereafter a gradual increase was observed from the January (1064) and reached the peak during April (2674), after which a decline in population was further observed. In

Table 5. Monthly population dynamics and diversity of *Bactrocera* species in mango orchard at Vellanikkara during August 2005 to July 2006

Sl. No	Month	Monthly mean catch from three standard ME traps			
		B. dorsalis	*B. caryae*	*B. correcta*	*B. zonata*
1	August 2005	1148	45	69	29
2	September	971	101	44	34
3	October	831	79	27	25
4	November	424	34	0	0
5	December	406	69	0	0
6	January 2006	1064	65	46	49
7	February	2202	167	45	33
8	March	2405	85	0	0
9	April	2674	90	0	0
10	May	2204	80	44	37
11	June	1554	68	42	25
12	July	1354	51	10	0
	Total	17,237	934	327	232
	Mean	1436.4	77.8	27.2	19.3
	Species composition (%)	92.02	4.98	1.74	1.23

Plate 16. Mango fruit fly *Bactrocera dorsalis* (Hendel) male adult

Plate 17. Mango fruit fly *Bactrocera dorsalis* (Hendel) female adult

Plate 18. Fruit fly *Bactrocera correcta* (Bezzi)

Plate 19. Fruit fly *Bactrocera zonata* (Saunders)

Plate 20. Fruit fly *Bactrocera caryeae* (Kapoor)

the rainy months of June (1554) and July 2006 (1354), a moderate population was observed.

The trap catch of *B. caryeae* remained at a low level throughout the study period with an average catch of 77.8 flies only. The highest catch of 167 nos. was recorded during February, 2006 followed by that in September, 2005 (101).

The average trap catch of *B. correcta* was only 27.2. There was no occurrence of the fly species during the months of November, December, February and March.

Same trend was observed with *B. zonata* species giving an average catch of 19.3 flies only which was lowest one among all the other species.

4.1.5 Population parameters of fruit flies

The population parameters of fruit flies caught in methyl eugenol traps at Vellanikkara during the study period are furnished in Table 6.

The species richness (S) value determined was four at Vellanikkara which is a direct measure of indication of fruit fly species composition responding to methyl eugenol in ME traps.

The species diversity as represented by the Simpson-Yule Diversity Index (D) showed a value of 1.38 in the over all range of 1 to 4. The low D value indicates a low species diversity in the community with a few dominant species. The Shannon-Weaver Diversity Index (H) of the fruit fly population determined was 0.58 in the range of 0 to 1.38. A low H value indicated a high magnitude of environmental stress favouring the dominance of a few adapted species. The Shannon-Weaver Evenness Index (E) estimated was 0.42, within its range of 0 to 1. The low E value indicated that the species present in the community have unequal members of individuals. The Berger-Parker Dominance Index (d) worked out showed a value of 0.96 within

Table 6. Ecological population parameters of the orchard fruit fly complex *Bactrocera* species at Vellanikkara

Population parameters	Symbol	Value	Range
1. Species richness	S	4.00	0-∝
2. Species diversity			
a) Simpson-Yule Diversity Index	D	1.38	1-4
b) Shannon-Weaver Diversity Index	H	0.58	0-1.38
c) Shannon-Weaver Evenness Index	E	0.42	0-1
d) Berger-Parker Dominance Index	d	0.96	0-1

0-1 range indicating a high magnitude of dominance by *B. dorsalis* among the different fruit fly species responding to methyl eugenol at Vellanikkara.

4.1.6 Determination of sex ratio and sex factor relationship in *B. dorsalis*

Sex ratio and sex factor relationships of *B. dorsalis* determined in different stages of mango fruit development and in other fruit crops are furnished in Tables 7 and 8.

In mango during different growth stages, (marble stage, lemon stage, ripened fruit and in cracked fruits), the observation on sex ratio of adult emergence revealed that it was more male biased in its population during summer. Among the mango growth stages, ripened fruit stage was having a higher male biased (1:0.99) ratio than the other stages. The sex ratio determined on ripened guava fruit revealed that the ratio was more female biased (1:1.06) while, in other fruit crops like bread fruit, rose apple and fig, it was rather male biased, with the sex ratio values being 1:0.86, 1:0.97, 1:0.94 for bread fruit, rose apple and fig respectively. The sex factor determined was 0.51, 0.46, 0.49 and 0.48 respectively on ripened guava, bread fruit, rose apple and fig during their fruiting seasons.

However, the ratio analysis and chi-square test revealed a non significant departure from a normal 1:1 ratio at all different growth stages of mango, ripened guava, bread fruit, rose apple and fig.

4.2 HEIGHT DETERMINATION OF ME BOTTLE TRAPS IN MANGO TREES FOR MANGO FRUIT FLY LURE TRAPPING

a) Determination of optimum trapping height on mango trees using the bottle traps during rainy periods

The mean total catch of fruit flies showed a significant difference among the different heights (Table 9) when observed for eight weeks.

The mean maximum MFF catch in ME traps was recorded at two metre height with 111.9 flies. The next higher catch was at four metre height (100.4) followed by six metres (80.7). The trap set at ground level recorded the lowest catch of 67.7 flies.

Table 7. Sex ratio and sex factor relationships of *B. dorsalis* in different growth stages of mango fruits (2006)

Sl. No.	Stages	Sex ratio	SD	Sex factor	SD
1	Marble stage	0.95	0.05	0.48	0.01
2	Lemon stage	0.90	0.03	0.47	0.05
3	Ripe mango	0.99	0.09	0.49	0.02
4	Cracked mango	0.98	0.08	0.49	0.02

Table 8. Sex ratio and sex factor relationships of *B. dorsalis* in different host fruits (2006)

Sl. No.	Fruits	Sex ratio	SD	Sex factor	SD
1	Ripe guava	1.06	0.14	0.51	0.03
2	Bread fruit	0.86	0.01	0.46	0.01
3	Rose apple	0.97	0.07	0.49	0.02
4	Fig	0.94	0.04	0.48	0.01

b) Determination of optimum trapping height on mango trees using the bottle traps during non rainy periods

The mean total catch of fruit fly showed a significant difference among the different heights (Table 10).

Among the different trap heights set on mango trees, in non rainy season, two metre height had maximum fruit fly mean catch with 63.9 flies followed by that at four metre height (48.2) and at ground level (41.3). The mean catch at six metre height recorded the lowest catch of 24 flies.

4.2.1 Determination of trapping height and directional attraction of sticky lure swabbing techniques in different fruit crops against mango fruit fly

a) Trap catch of MFF in sticky lure swabs on mango tree

The results of trapping height and direction of attraction in mango against fruit fly are presented in Table 11.

Among the different trapping heights tried, it was observed that highest number of flies were trapped in the sticky swabs at 2 metres (6.56) followed by 1.5 metre (5.19) and 1 metre (4.96). Sticky swabs at ground level, 0.5 m and 2.5 m height showed lower catches with 3.24, 3.18 and 3.40 flies respectively.

Mean fruit fly catch with respect to the directional orientation to East, West, North and South sides on the tree trunk showed higher number of attraction in the western side with 7.48 flies at all the heights as compared to that in the South direction (5.24). Fruit fly attraction was found to be low towards the eastern and northern direction with an average trap catches of 2.48 and 2.5 flies respectively.

b) Trap catch of MFF in sticky lure swabs on bread fruit tree

The results of trapping height and directional attraction of fruit flies in bread fruit are presented in Table 12 and Plate 21.

Table 9. Trapping heights and fruit fly catch in ME bottle traps on mango trees during rainy season

Heights	Weekly mean catch / Standard weeks								Mean FF catch
	June 22/06	23/06	24/06	25/06	26/06	July 27/06	28/06	29/06	
1. Ground level	64.3[d] (8.04)	71.6[d] (8.49)	74.3[d] (8.64)	82.6[d] (9.11)	83.3[d] (9.15)	71.3[d] (8.47)	52.3[c] (7.26)	42.3[d] (6.54)	67.7[d] (8.25)
2. 2 m	113.3[a] (10.66)	120.6[a] (11.0)	125[a] (11.20)	135[a] (11.64)	129[a] (11.37)	100[a] (10.02)	89[a] (9.46)	84[a] (9.19)	111.9[a] (10.6)
3. 4 m	104[b] (10.22)	115[b] (10.74)	105.6[b] (10.30)	115.3[b] (10.76)	109[b] (10.46)	95.6[b] (9.80)	86.6[a] (9.33)	72.6[b] (8.54)	100.4[b] (10.04)
4. 6 m	80.6[c] (9.00)	82.3[c] (9.09)	92.3[c] (9.63)	100.6[c] (10.05)	100.6[c] (10.05)	75.3[c] (8.7)	62.3[b] (7.92)	52.3[c] (7.26)	80.7[c] (9.01)

In a column, means superscripted by a common letter are not significantly different by DMRT (P = 0.05)
Values in parentheses are after square root transformation

Table 10. Trapping heights and fruit fly catch in ME bottle traps on mango trees during non rainy season

Heights	Weekly mean catch / Standard weeks								Mean FF catch
	Nov. II 45/05	46/05	47/05	48/05	Dec. 49/05	50/05	51/05	52/05	
1. Ground level	30.6[b] (5.57)	43[c] (6.59)	42.3[c] (6.54)	49.3[c] (7.05)	50[c] (7.10)	42.3[c] (6.54)	40[b] (6.36)	33.6[b] (5.83)	41.3[c] (6.46)
2. 2 m	42.3[a] (6.54)	67[a] (8.21)	70.6[a] (8.43)	81.6[a] (9.06)	84.3[a] (9.20)	60.6[a] (7.81)	55.3[a] (7.46)	49.6[a] (7.07)	63.9[a] (8.02)
3. 4 m	31[b] (5.61)	53.6[b] (7.35)	51.6[b] (7.21)	62.6[b] (7.94)	63[b] (7.96)	50[b] (7.10)	40.6[b] (6.41)	33.3[b] (5.63)	48.2[b] (6.97)
4. 6 m	21[c] (4.63)	20.6[d] (4.59)	23.3[d] (4.87)	32.3[d] (5.72)	32.3[d] (5.72)	22.6[d] (4.8)	24.6[c] (5.00)	15.6[c] (4.01)	24.0[d] (4.94)

In a column, means superscripted by a common letter are not significantly different by DMRT (P = 0.05)
Values in parentheses are after square root transformation

Table 11. Trapping heights and directional orientation of MFF to sticky lure swabs in mango tree

Directions / Heights (m)	Number of FF entrapped in lure swabs (10 cm^2)				
	East	West	North	South	Mean catch
Ground level	1.12^e (1.27)	6.26^c (2.6)	1.20^d (1.30)	4.40^c (2.21)	3.24^c (1.93)
0.5	1.40^d (1.37)	5.12^d (2.37)	1.60^d (1.44)	4.60^c (2.25)	3.18^c (1.91)
1	3.06^b (1.88)	8.20^b (2.94)	3.00^b (1.87)	5.60^b (2.46)	4.96^b (2.33)
1.5	3.20^b (1.92)	8.86^b (3.05)	3.00^b (1.87)	5.72^b (2.49)	5.19^b (2.38)
2	4.06^a (2.13)	11.0^a (3.39)	4.00^a (2.12)	7.20^a (2.77)	6.56^a (2.65)
2.5	2.04^c (1.59)	5.46^d (2.44)	2.20^c (5.64)	3.92^d (2.10)	3.40^c (1.97)
Mean	2.48^c (1.72)	7.48^a (2.82)	2.50^c (1.70)	5.24^b (2.39)	

In a column, means superscripted by a common letter are not significantly different by DMRT (P = 0.05)

Values in parentheses are after square root transformation

Table 12. Trapping heights and directional orientation of MFF to sticky lure swabs in bread fruit

Directions / Heights (m)	Number of FF entrapped in lure swabs (10 cm^2)				
	East	West	North	South	Mean catch
Ground level	0.40^d (0.94)	4.04^c (2.13)	0.40^e (0.94)	3.80^c (2.07)	2.16^c (1.63)
0.5	0.72^d (1.10)	4.40^c (2.21)	0.84^d (1.15)	3.20^d (1.92)	2.29^c (1.67)
1	1.20^c (1.30)	5.40^b (2.42)	1.20^c (1.30)	4.60^b (2.25)	3.10^b (1.89)
1.5	1.60^b (1.44)	6.00^b (2.54)	1.60^b (1.44)	4.80^b (2.30)	3.50^b (2.03)
2	2.60^a (1.76)	8.40^a (2.98)	2.40^a (1.70)	6.00^a (2.54)	4.85^a (2.29)
2.5	1.00^c (1.22)	3.56^d (2.01)	1.06^c (1.24)	2.64^e (1.77)	2.06^c (1.60)
Mean	1.25^c (1.32)	5.30^a (2.40)	1.25^c (1.32)	4.17^b (2.16)	

In a column, means superscripted by a common letter are not significantly different by DMRT (P = 0.05)

Values in parentheses are after square root transformation

Lure swab trap pasted at the two metre height caught significantly more number of flies (4.85) followed by 1.5 metre (3.50), one metre (3.10), 0.5 metre (2.29) and at ground level (2.16). 2.5 metre height recorded the lowest catch of 2.06 flies.

The directional orientation of fruit flies in breadfruit was also recorded to be higher towards the western direction with an average catch of 5.30 nos. followed by the same towards south (4.17), north (1.25) and east (1.25).

The overall mean data over five weeks of observation on trapping height and direction of attraction in mango and bread fruit resulted that, the 2 metre height and western direction was the best location for the lure swab trapping of the fruit flies.

c) Trap catch of MFF in sticky lure swabs on sapota tree

The results of trapping height in sapota against fruit fly are furnished in Table 13 and Plate 22.

Swab trap pasted at 1.5 metre height had the maximum mean catch of 7.0 flies followed by 4.72 flies at 2 m height, 3.90 flies at 2.5 m height, 3.32 flies at one metre height. 0.5 m height and ground level recorded the lowest mean trap catches of 1.96 and 1.0 flies respectively.

4.3 PHENOLOGICAL STUDY ON THE PEACE LILLY (*Spathiphyllum cannaefolium*) FLOWERING AND MFF ATTRACTION

The results on the MFF attraction to *Spathiphyllum* flowers are furnished in the Table 14.

The total active period of fruit fly attraction on to the *Spathiphyllum* flowers in the MFF attraction was found to be for 19 days. For the first two days, the attraction was very low (2.0 - 4.1 flies). From the third to eighth day there was an ascending trend in the attraction of flies which ranged between 6.2 to 8.4 flies). The partially unopened flower bud (Plate 23) also attracted the fruit flies (2 flies). The milky white coloured

Table 13. Trapping heights of MFF of sticky lure swab in sapota

Heights (m) / Weeks	Number of fruit fly entrapped in lure swabs (5 cm^2)					
	Ground level	0.5	1	1.5	2	2.5
Feb. 4^{th}	0^{e} (0.71)	1^{d} (1.22)	2^{b} (1.58)	4^{a} (2.12)	2^{b} (1.58)	1.6^{c} (1.44)
Mar. 1^{st}	1^{e} (1.22)	1.6^{de} (1.44)	2.3^{c} (1.67)	6^{a} (2.54)	3^{b} (1.87)	2^{cd} (1.58)
Mar. 2^{nd}	1^{f} (1.22)	2.6^{e} (1.76)	3^{de} (1.87)	8^{a} (2.91)	5^{b} (2.34)	3.6^{c} (2.02)
Mar. 3^{rd}	2^{d} (1.58)	2.6^{d} (1.76)	4^{c} (2.12)	10^{a} (3.24)	8^{b} (2.91)	8^{b} (2.91)
Mar. 4^{th}	1^{e} (1.22)	2^{d} (1.58)	2.3^{d} (1.67)	7^{a} (2.73)	5.6^{b} (2.46)	4.3^{c} (2.19)
Total	5.00 (2.34)	9.80 (3.2)	16.6 (4.13)	35.0 (5.95)	23.6 (4.9)	19.5 (4.47)
Mean	1.0^{e} (1.22)	1.96^{d} (1.56)	3.32^{c} (1.95)	7.0^{a} (2.73)	4.72^{b} (2.28)	3.9^{c} (2.09)

In a column, means superscripted by a common letter are not significantly different by DMRT (P = 0.05)

Values in parentheses are after square root transformation

Table 14. Diurnal rhythm of fruit fly attraction on to the spadix of peace lily *Spathiphyllum cannaefolium*

	Time of attraction*													Mean
Days	6 am	7 am	8 am	9 am	10 am	11 am	12 n.	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm	
1	1.0	2.0	4.3	2.3	1.6	1.0	-	-	-	-	-	-	-	2.03
2	1.3	5.3	10.0	5.0	2.0	1.3	-	-	-	-	-	-	-	4.15
3	2.0	8.6	20.6	10.3	3.3	2.0	1.6	1.3	-	-	-	-	-	6.21
4	3.0	10.6	20.0	10.3	7.0	3.6	1.6	1.0	-	-	-	-	-	7.13
5	3.3	10.3	20.0	10.0	9.3	3.0	1.3	1.0	-	-	-	-	-	7.20
6	2.6	10.0	25.3	10.0	6.0	2.6	1.3	1.0	-	-	-	-	-	7.30
7	2.3	13.0	25.3	14.6	6.0	2.6	1.0	1.0	-	-	-	-	-	8.20
8	2.3	15.3	23.0	15.3	7.6	2.3	1.0	0.6	-	-	-	-	-	8.40
9	2.0	10.6	20.6	13.0	5.3	2.3	1.0	0.6	-	-	-	-	-	6.90
10	2.0	10.0	20.0	13.0	5.0	2.0	1.0	-	-	-	-	-	-	6.62
11	2.0	7.3	15.6	8.3	3.6	2.0	1.0	-	-	-	-	-	-	5.68
12	2.0	7.0	15.0	8.0	2.6	2.0	1.0	-	-	-	-	-	-	5.30
13	2.0	5.6	10.6	5.3	2.3	1.6	0.6	-	-	-	-	-	-	4.00
14	1.3	5.0	10.3	5.0	2.0	1.3	-	-	-	-	-	-	-	4.90
15	1.0	3.3	10.0	5.0	2.0	1.3	-	-	-	-	-	-	-	4.50
16	-	3.0	7.0	4.6	1.6	1.0	-	-	-	-	-	-	-	3.40
17	-	1.6	4.3	2.0	1.3	1.0	-	-	-	-	-	-	-	2.00
18	-	1.0	2.0	1.3	1.0	1.0	-	-	-	-	-	-	-	3.10
19	-	-	1.0	1.0	-	-	-	-	-	-	-	-	-	1.10
Total	30.1	129.5	264.9	144.3	69.5	33.9	12.4	6.5	-	-	-	-	-	-
Mean	2.00	7.19	13.9	7.59	3.86	1.88	1.12	0.92	-	-	-	-	-	-

* Spadix from half emergence with milky white colour till change to green

Plate 21. Fruit flies on sticky lure swab trap on Bread fruit tree trunk

Plate 22. Fruit flies on sticky lure swab trap on Sapota tree trunk

spadix (Plate 24) attracted more number of fruit flies than the green spadix and also the withered ones.

The fruit flies were found to be attracted to spathiphyllum flowers from 6 am to 1 pm and after that no flies were observed on it. The maximum number of flies attracted were between 7 to 8 am, giving a total fly attraction of 13.9 nos. during the active days of inflorescence. The number of flies attracted ranged between 1 - 25.3 during the period of observation. The respective number of flies attracted during the hours at 5 - 6, 6 - 7, 7 - 8, 8 - 9, 9 - 10, 10 - 11 am, 11 - 12 noon and 12 - 1 pm were 2.0, 7.1, 13.9, 7.5, 3.8, 1.8, 1.1 and 0.92 flies. It was also observed that the prevalent rains did not have any adverse effect on the attraction of fruit flies to spadix during rainy days.

4.4 MANGO FRUIT FLIES AND THEIR PHENOLOGICAL RELATIONSHIP WITH MANGO TREES

a) Alightment of MFF on mango trees during flushing time

The results on the investigation of MFF and their alightment behaviour during the flushing time in mango are presented in the Table 15.

Among the branches observed, tertiary branches (Plate 25) hosted the maximum number of fruit flies of 1.3 flies per 30 cm^2 area and lesser number of flies were observed on the secondary branches (0.9 flies). No flies could be observed on the main trunk and primary branches.

When the leaves were observed for the alightment of adult MFF, under side of leaves (Plate 26) in the lower canopy recorded highest number of mango fruit flies (2.4 flies per 30 cm^2 area) followed by leaves in the middle canopy with an average of 1.7 flies. The under side of leaves of top canopy hosted only an average number of 1.0 flies. On the upper side of leaves in the middle canopy of the tree had only one number of MFF/30 cm^2 could only be recorded. There was no flies on upper side of leaves belonging to lower and top canopy.

Table 15. Distribution of alighted fruit flies on mango trees at flushing time

Sl. No.	Plant parts	Mean (No. of flies)
1	Main trunk	0.0 (0.71)^{e}
2	Primary branches	0.0 (0.71)^{e}
3	Secondary branches	0.9 (1.18)^{d}
4	Tertiary branches	1.3 (1.34)^{c}
5	Leaves (under side)	
	a. Lower canopy	2.4 (1.70)^{a}
	b. Middle canopy	1.7 (1.48)^{b}
	c. Top canopy	1.0 (1.22)^{d}
6	Leaves (upper side)	
	a. Lower canopy	0.0 (0.71)^{e}
	b. Middle canopy	1.0 (1.22)^{d}
	c. Top canopy	0.0 (0.71)^{e}

In a column, means superscripted by a common letter are not significantly different by DMRT (P = 0.05)

Values in parentheses are after square root transformation

Plate 23. ***Bactrocera dorsalis*** **male flies alighting on emerging** ***Spathiphyllum*** **spadix**

Plate 24. ***Bactrocera dorsalis*** **male flies on** ***Spathiphyllum*** **spadix**

Plate 25. Dead mango fruit fly located on the fork of the tree trunk

Plate 26. ***Bactrocera dorsalis*** **adult fly alightment on underside of mango leaf during flushing time**

Among the levels of branches and sides of leaves observed, the under side of leaves on the lower canopy branches of trees ranked with the highest alightment number of fruit flies.

b) Alightment of MFF on mango trees at fruiting time

Observation on the alightment of mango fruit fly at fruiting time on mango tree is presented in the Table 16.

When the branches were observed, the secondary and tertiary branches were found to be alighted with maximum number of adult flies with an average of one fly.

When the fruits were observed, the proximal end of fruits in the lower canopy hosted the highest number of mango fruit flies (Plates 27 and 28) with an average of 1.3 flies and the middle part of the fruit with one fly only per fruit. The proximal end and middle part of the fruits in the middle canopy also hosted with one fly each while the distal end of the fruit hosted with 0.8 fly only. The same observation from the top canopy recorded one and 0.8 fly per fruit at proximal end and middle part of the fruit respectively.

4.5 EMERGENCE RHYTHM OF MANGO FRUIT FLIES IN MANGO ORCHARDS

Observations on the emergence of mango fruit flies are presented in Table 17.

The emergence of fruit flies observed from the ground soil in the mango orchard from February (first week) onwards till May (second week).

The higher mean number of adult flies observed in the emergence trap were at 2 m radial distance from the tree base during February second week with 20 flies in the North Eastern direction followed by that in February third week (15 flies in North direction) and February second week (15 flies in north East direction).

Table 16. Distribution of alighted fruit flies on mango trees at fruit maturity time

Sl. No.	Plant parts	Mean (No. of flies)
1	Main trunk	0.0 (0.71)^{d}
2	Primary branches	0.0 (0.71)^{d}
3	Secondary branches	1.0 (1.22)^{b}
4	Tertiary branches	1.0 (1.22)^{b}
5	Fruits (Lower canopy)	
	a) Proximal end	1.0 (1.22)^{b}
	b) Middle fruit	1.0 (1.22)^{b}
	c) Distal end	0.8 (1.14)^{c}
6	Fruits (Middle canopy)	
	a) Proximal end	1.3 (1.34)^{a}
	b) Middle part	1.0 (1.22)^{b}
	c) Distal end	0.9 (1.18)^{bc}
7	Fruits (Top canopy)	
	a) Proximal end	1.0 (1.22)^{b}
	b) Middle part	0.8 (1.14)^{c}
	c) Distal end	0.0 (0.71)^{d}

In a column, means superscripted by a common letter are not significantly different by DMRT (P = 0.05)

Values in parentheses are after square root transformation

Table 17. Spatial distribution of MFF adult emergence from the soil litter of mango tree

Weeks	East			West			North			South			N. East			S. East			S. West			N. West		
	1*	2*	3*	1*	2*	3*	1*	2*	3*	1*	2*	3*	1*	2*	3*	1*	2*	3*	1*	2*	3*	1*	2*	3*
Feb I		9			5			11			2													
II														15	2.5		4.5			2			7	4
III		10			5			15	2		3													
IV														20	5		4.5	4		5			11	2
March I		14.5	11		11	2		25	20		5	2												
II														31	25		5	2		10	4		15	10
III		7	3		5	2		16	11		5.5	5												
IV														21	16		5.5	5		5	2.5		10	5.5
April I		14.5	9		10	2		24	11		3.5	5												
II														25	20		5	3		5	2		10	7.5
III		7.5	3.5		5	3		17.5	4.5		3	2												
IV														21	7.5		4.5	2.5		5	2		7	5
May I		2.5			2			5			0													
II														7.5			2	0		0			3	
Mean		9.2	4.4		6.1	1.5		16.2	8.1		3.1	2.3		20.1	12.6		4.4	2.8		4.6	1.8		9	5.7
Total	13.6 ^{c} (3.75)			7.6 ^{d} (2.84)			24.3 ^{b} (4.97)			5.4 ^{e} (2.42)			32.7 ^{a} (5.76)			7.2 ^{d} (2.77)			6.4 ^{de} (2.62)			14.7 ^{c} (3.89)		

* Radial distance in metres from the tree base

In a column, means superscripted by a common letter are not significantly different by DMRT (P = 0.05)

Values in parentheses are after square root transformation

Plate 27. ***Bactrocera dorsalis*** **female adult fly before oviposition on mango fruit**

Plate 28. ***Bactrocera dorsalis*** **female fly during oviposition on the mango fruit**

In March, the maximum number of fruit fly emergence was noticed in the second week with 31 flies in North East direction at 2 m distance from the tree base followed by 25 flies at 3 m distance in the North East direction in March second week and 25 flies during first week of March at north direction at 2 m distance from the tree base.

In the month of April, the highest emergence catch was recorded during the second week (25 flies) in the North East direction and first week (24 flies) in North direction. During May the less number of adult fly was emerged out from the soil.

During the entire season under observation, the maximum emergence was recorded during second week of March with 31 flies followed by first week of the same month with 25 flies in the emergence traps.

As far as directional orientation was concerned the maximum fly emergence from the soil was noticed in the North East direction (mean of 32.7 flies) followed by North direction (mean of 24.3 flies).

The hourly rate of emergence of adult fruit flies from the soil substrate during the day time as caught in the emergence trap are furnished in Table 18.

The time of adult fly emergence was observed to at higher proportion from 6 am (mean of 4.6 flies) to 10 am (mean of 3.8 flies) and the peak hour of emergence was noticed at 6-7 am period (mean of 8.6 flies). After 10 am there was no emergence noticed as per the entrapped flies in the emergence trap.

4.6 THE COMPARATIVE EVALUATION OF FOOD LURES ON THE MFF ORIENTATION AND DISTRIBUTION UNDER CAGE EXPERIMENTATION BY THE SINGLE KILLING POINT (SKP) METHOD

The results of the SKP studies are presented in Table 19.

Table 18. Diurnal emergence pattern of MFF from the mango orchard

Weeks	Time of emergence*												
	6 am	7 am	8 am	9 am	10 am	11 am	12 noon	1 pm	2 pm	3 pm	4 pm	5 pm	6 pm
Mar. I	5.3	12.6	10.0	4.3	4.0	-	-	-	-	-	-	-	-
Mar. II	4.6	15.0	7.6	5.0	4.6	-	-	-	-	-	-	-	-
Mar.III	4.0	10.3	8.3	3.3	3.0	-	-	-	-	-	-	-	-
Mean	4.6[c] (2.25)	12.6[a] (3.61)	8.6[b] (3.01)	4.2[cd] (2.16)	3.8[d] (2.07)								

* Total fly catch from the three emergence traps
In a column, means superscripted by a common letter are not significantly different by DMRT (P = 0.05)
Values in parentheses are after square root transformation

Table 19. The comparative evaluation of food lures on MFF orientation and attraction under SKP cage experimentation

Comparisons	Food lures	Mean fruit flies	Food lures	Mean fruit flies	't' value
C_1	Palayankodan	8.0	Jaggery	4.3	5.50**
C_2	Palayankodan	4.0	Robusta	8.6	7.00**
C_3	Robusta	6.6	Poovan	8.6	2.68*
C_4	Fig	4.0	Rose apple	9.0	8.66**
C_5	Guava	6.6	Pappaya	4.6	4.24*
C_6	Mango unpeeled	7.6	Mango peeled	6.6	2.12^{NS}
C_7	Prior	8.6	Muvandan	4.6	8.49**
C_8	Neelam	2.6	Banganappalli	6.6	5.37**
C_9	Alphonsa	7.0	Ollur	4.6	3.50*

** Significant at 1% level

* Significant at 5% level

Among the comparisons (C1), the Palayankodan banana swab treatment was more attractive with a total fly count of 8 while, jaggery swab attracted only 4.3 flies. In C2, Robusta banana swab attracted 8.6 flies while Palayankodan attracted 4 flies only. In C3, Poovan banana swab was giving highest count with 8.6 fly while Robusta attracted only 6.6 flies.

In C4, the rose apple fruit piece attracted more fruit flies (9 flies), while fig fruit piece attracted only 4 flies. In C5, the Guava fruit piece was attracting higher number with a fly count of 6.6 while, papaya fruit piece attracted 4.6 flies only. In C6, the unpeeled mango attracted 7.6 flies, while peeled mango fruit piece attracted a lesser number of 6.6 flies only.

In C7, the fruit piece of Prior variety mango attracted higher number of flies (8.6) than Muvandan fruit piece with 4.6 flies only. In C8, the Banganapalli mango piece performed better with a mean of 6.6 flies while, Neelam fruit piece was less attractive with 2.6 flies. In C9, the fruit piece of Alphonsa variety mango was better in its attraction than the Olour mango (7 and 4.6 number of MFF respectively).

Among the different fruit macerates of banana tested, the Robusta and Poovan varieties ranked the bests in total attraction and fruit fly orientation. Among different fruit pieces tested, Prior variety of mango and Rose apple fruit ranked toppers in the total fruit fly orientation counts.

4.7 EFFICACY OF ME BOTTLE TRAPS TO MFF UNDER SHADED AND UNSHADED AREAS

The results showed that (Table 20) there was more attraction of MFF in terms of catch per trap in shaded areas than the unshaded areas. The peak time of attraction in shaded area was between 4 to 6 pm (41.8 flies/trap). Moderate attraction was noticed in the morning hours between 6 to 8 am (33.5 flies/trap) in shaded areas. During noon time between 12 to 2 pm, the ME traps under both shaded and unshaded area had the lowest attraction of fruit flies with 10.4 and 2.8 flies respectively.

Table 20. Diurnal response of MFF to ME traps under shaded and unshaded exposures in the orchard

Days	Total fruit fly catches at two hour intervals*											
	6-8 am		8-10 am		10-12 noon		12-2 pm		2-4 pm		4-6 pm	
	S	US	S	US	S	US	S	US	S	US	S	US
1-4-07	35.3	14.6	25.6	4.6	14.6	2	10.6	3	23.6	6	42.6	17.3
2-4-07	34.6	12	25.3	4.3	16	2.3	10.6	3	24	5.6	42.3	17.3
3-4-07	30.6	9.3	22.6	4	13.3	2.3	10	2.6	23.6	5.0	40.6	16.0
Mean	33.5 ^{b} (5.83)	11.9 ^{f} (3.52)	24.5 ^{c} (5.0)	4.3 ^{g} (2.19)	14.6 ^{e} (3.88)	2.2 ^{h} (1.64)	10.4 ^{f} (3.30)	2.8 ^{h} (1.81)	23.73 ^{c} (4.92)	5.5 ^{g} (2.44)	41.8 ^{a} (6.50)	16.8 ^{d} (4.15)

* - The figures are mean of three traps catches during the non rainy days of April

S - Shaded area

US - Unshaded area

In a column, means superscripted by a common letter are not significantly different by DMRT (P = 0.05)

Values in parentheses are after square root transformation

4.8 SPATIAL DISTRIBUTION AND SPREAD OF MANGO FRUIT FLY *B. dorsalis*

The mean catch of fruit flies per week per trap observed at 10 locations in Thrissur and Palakkad districts showed a significant difference in their prevalence and spread (Table 21 and Fig. 2) during November fourth week to June third week (48 standard weeks of 2006 to 24 standard weeks of 2007).

The data on the MFF mean catch per trap per week at Paravattani area of Thrissur district showed a lower catch ranging from 25 to 39.3 flies from November fourth week 2006 to second week of January 2007 (48^{th} to 2^{nd} standard week of 2006-07). After that, there was a gradual increase in fly population which reached the peak on 3^{rd} week of April (372 flies) and further show a gradual decrease to 172.5 flies/trap/week.

In Mannuthy location, a lower catch of 42 to 49.3 flies was observed from the fourth week of November to the second week of January and after that there was a gradual increase and reached the peak by 10^{th} standard week of 2007 (March second week, 310 flies) and again by 12^{th} standard week of 2007 (March fourth week, 315.6 flies) and subsequently the population was on a decreasing trend.

In Vellanikkara location also there was a low level of population as observed from November to second week of January (36.3 - 40 flies). The peak populations were observed during the 11^{th} standard week of 2007 (March third week with 256.6 flies) and 14^{th} standard week of 2007 (April first week with 283.6 flies). After that the population got decreased.

In Pattikadu and Vadakkenchery locations, there were very low levels population as observed during the entire study period without any peaks as compared to other locations.

Table 21. Flowering phenology and relative population levels of MFF in different mango orchard systems across 75 km from Thrissur to Tamil Nadu border during 2006-07

Locations	Mean weekly fruit fly catch responding to ME traps										
	Nov. IV 48/06	Dec. 49/06	50/06	51/06	52/06	Jan. 1/07	2/07	3/07	4/07	Feb. 5/07	6/07
1. Paravattani	25^{e} (5.04)	25^{e} (5.04)	20^{e} (4.52)	21.3^{d} (4.66)	26.3^{f} (5.17)	42.6^{c} (6.56)	39.3^{d} (6.30)	73.6^{d} (8.60)	98^{d} (9.92)	82^{h} (9.08)	132.3^{d} (11.52)
2. Mannuthy	42^{b} (6.51)	42^{c} (6.51)	36^{c} (6.04)	41.3^{b} (6.46)	50.6^{b} (7.14)	48.3^{b} (6.98)	49.3^{b} (7.05)	72.3^{d} (8.53)	90^{e} (9.51)	111.3^{f} (10.57)	139^{c} (11.81)
3. Vellanikkara	36.3^{c} (6.06)	32.6^{d} (5.75)	31.3^{d} (5.63)	32.6^{c} (5.75)	40^{d} (6.36)	40.6^{d} (6.41)	40^{d} (6.36)	55^{f} (7.44)	85.6^{f} (9.27)	99.3^{g} (9.98)	123.3^{e} (11.12)
4. Pattikkadu	9.3^{f} (3.13)	10^{g} (3.24)	12^{f} (3.53)	8.3^{f} (2.96)	22^{g} (4.74)	19^{f} (4.41)	22^{e} (4.74)	23.6^{g} (4.90)	33.3^{g} (5.81)	33.3^{j} (5.81)	27.6^{g} (5.30)
5. Vadakkencherry	11.6^{f} (3.47)	17.6^{f} (4.25)	10^{f} (3.24)	13.3^{e} (3.71)	22.6^{g} (4.80)	24.3^{e} (4.97)	23^{e} (4.84)	23.6^{g} (4.90)	34.6^{g} (5.92)	40^{i} (6.36)	42.3^{f} (6.54)
6. Nenmara	37^{c} (6.12)	31.6^{d} (5.66)	32^{d} (5.70)	30.6^{c} (5.57)	44^{c} (6.67)	45^{c} (6.74)	43.6^{c} (6.64)	63.6^{e} (8.00)	86^{f} (9.30)	115^{e} (10.74)	134^{d} (11.59)
7. Kollengodu	60.6^{a} (7.81)	53.3^{a} (7.33)	52^{a} (7.24)	42^{b} (6.51)	56^{a} (7.51)	54^{a} (7.38)	61.6^{a} (7.88)	89.6^{c} (9.49)	116.3^{c} (10.80)	142.3^{d} (11.94)	179.3^{b} (13.40)
8. Muthalamada	32^{d} (5.70)	42^{c} (6.51)	43^{b} (6.59)	40.6^{b} (6.41)	41.3^{d} (6.46)	46.6^{b} (6.86)	52^{b} (7.24)	96^{b} (9.82)	121.6^{b} (11.04)	151.6^{b} (12.33)	180.6^{b} (13.45)
9. Nariparachella	32.3^{d} (.5.72)	45.3^{b} (6.67)	44^{b} (6.67)	45.3^{a} (6.76)	36^{e} (6.04)	45.6^{b} (6.78)	43^{c} (6.59)	106^{a} (10.31)	132.3^{a} (11.52)	155.6^{a} (12.49)	185.6^{a} (13.64)
10. Sadayanpallam	32.6^{d} (5.75)	40.3^{c} (6.38)	45^{b} (6.74)	44^{a} (6.67)	44.6^{c} (6.71)	42^{c} (6.51)	44.6^{c} (6.71)	97.3^{b} (9.88)	120^{b} (10.97)	145^{c} (12.06)	178.3^{b} (13.37)

Contd.

In a column, means superscripted by a common letter are not significantly different by DMRT (P = 0.05)
Values in parentheses are after square root transformation

Table 21. Continued

Locations	Mean weekly fruit fly catch responding to ME traps										
	7/07	8/07	March 9/07	10/07	11/07	12/07	13/07	April 14/07	15/07	16/07	17/07
1. Paravattani	134^{e} (11.59)	163.3^{g} (12.79)	210^{f} (14.50)	237.3^{e} (15.42)	275^{e} (16.59)	296.6^{e} (17.23)	303.3d (17.42)	327.5^{d} (18.11)	360^{a} (18.98)	372^{b} (19.30)	291^{cd} (17.07)
2. Mannuthy	244^{c} (15.63)	258^{d} (16.07)	247.3^{d} (15.74)	310.0^{c} (17.62)	303.3^{d} (17.42)	315.6^{d} (17.17)	283.6^{e} (16.85)	282.3^{e} (16.81)	244.0^{f} (15.63)	260.6^{g} (16.15)	242.3^{g} (15.48)
3. Vellanikkara	152.3^{d} (12.36)	180^{e} (13.43)	215^{e} (14.67)	251.3^{f} (15.86)	256.6^{f} (16.03)	231.3^{f} (15.22)	233.6^{g} (15.30)	283.6^{e} (16.85)	272.3^{e} (16.51)	274.3^{f} (16.57)	251.3^{f} (15.86)
4. Pattikkadu	43.3^{f} (6.61)	49^{h} (7.03)	52.3^{g} (7.26)	62.3^{h} (7.92)	63.3^{h} (7.98)	72.3^{h} (8.53)	72.3^{h} (8.53)	82.3^{f} (9.09)	86.6^{g} (9.33)	91.6^{h} (9.59)	80.6^{h} (9.00)
5. Vadakkencherry	40^{f} (6.36)	45^{c} (6.74)	50.6^{g} (7.14)	53.3^{i} (7.33)	54^{i} (7.38)	62.3^{i} (7.92)	62.3^{i} (7.92)	68.0^{g} (8.27)	74.6^{h} (8.66)	72.3^{i} (8.53)	62.3^{i} (7.92)
6. Nenmara	150^{d} (12.26)	175^{f} (13.24)	210.3^{f} (14.51)	242.6^{g} (15.59)	251.3^{g} (15.86)	260.6^{f} (16.15)	272.3^{f} (16.51)	280.6^{e} (16.76)	306.6^{d} (17.52)	313.3^{e} (17.71)	282.6^{e} (16.82)
7. Kollengodu	233.6^{b} (15.3)	283.6^{b} (16.85)	315^{b} (17.76)	317.6^{b} (17.83)	330.6^{a} (18.19)	342.3^{a} (18.51)	354.3^{a} (18.83)	362.3^{a} (19.04)	363.3^{a} (19.07)	393.3^{a} (19.84)	353.3^{a} (18.80)
8. Muthalamada	231.3^{b} (15.22)	277.3^{c} (16.66)	320^{a} (17.90)	313.3^{c} (17.71)	315.3^{c} (17.77)	323.6^{c} (18.00)	324^{c} (18.01)	340.6^{bc} (18.46)	333.3^{c} (18.27)	351^{c} (18.74)	304.3^{b} (17.45)
9. Nariparachella	242.3^{a} (15.58)	292.3^{a} (17.11)	312.6^{b} (17.69)	330.6^{a} (18.19)	323.3^{b} (17.99)	330.6^{b} (18.19)	332.3^{b} (18.24)	343^{b} (18.53)	341.3^{b} (18.48)	344.3^{d} (18.56)	293^{c} (17.13)
10. Sadayanpallam	234.3^{b} (15.32)	283.6^{b} (16.85)	307^{c} (17.53)	310^{d} (17.62)	320.6^{b} (17.91)	316^{d} (17.79)	321.6^{d} (17.94)	338^{c} (18.39)	334.6^{c} (18.30)	341.6^{d} (18.49)	289.6^{d} (17.03)

Contd.

In a column, means superscripted by a common letter are not significantly different by DMRT (P = 0.05)

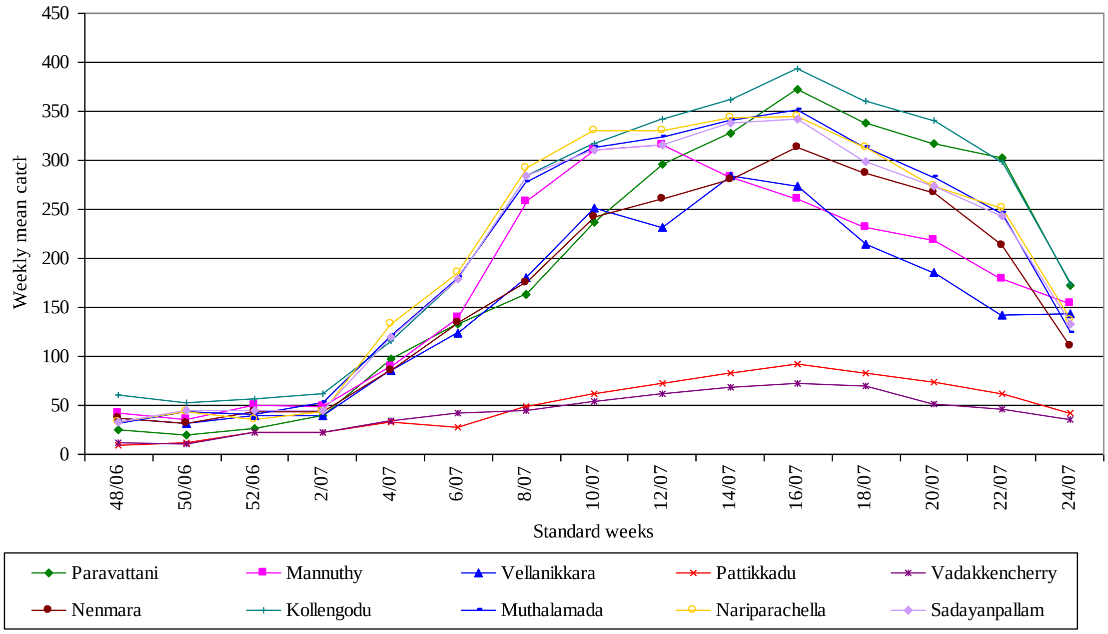
Values in parentheses are after square root transformation

Table 21. Continued

Locations	Mean weekly fruit fly catch responding to ME traps						
	May 18/07	19/07	20/07	21/07	June 22/07	23/07	24/07
1. Paravattani	338.5[b] (18.41)	349.5[a] (18.70)	317.5[b] (17.83)	302.5[a] (17.40)	302.5[a] (17.40)	202.5[a] (14.24)	172.5[a] (13.15)
2. Mannuthy	231.3[f] (15.22)	200.0[e] (14.15)	219.0[f] (14.81)	185.6[f] (13.64)	179.3[f] (13.40)	169.3[b] (13.03)	154[b] (12.42)
3. Vellanikkara	215.0[g] (14.67)	180.6[f] (13.45)	185.6[g] (13.64)	155.6[g] (12.49)	142.3[g] (11.94)	144[c] (12.02)	144[c] (12.02)
4. Pattikkadu	83.3[h] (9.15)	78[g] (8.86)	74[h] (8.63)	66.6[h] (8.19)	62.3[h] (7.92)	51[f] (7.17)	42.5[h] (6.55)
5. Vadakkencherry	70[i] (8.39)	51.6[h] (7.21)	51.3[i] (7.19)	48.3[i] (6.98)	46[i] (6.81)	42.6[g] (6.56)	35[i] (5.95)
6. Nenmara	286.3[e] (16.93)	274.3[d] (16.57)	266.6[e] (16.34)	252.3[d] (15.89)	213.3[e] (14.62)	121.6[e] (11.04)	110[g] (10.51)
7. Kollengodu	360.6[a] (19.00)	352.3[a] (18.78)	341.3[a] (18.48)	219[e] (14.81)	298.3[b] (17.28)	200[a] (14.15)	173.3[a] (13.18)
8. Muthalamada	312.6[c] (17.69)	300[b] (17.33)	283.3[d] (16.84)	263.3[c] (16.24)	245.6[d] (15.68)	133.3[d] (11.56)	124.3[f] (11.17)
9. Nariparachella	313[c] (17.70)	288.3[c] (16.99)	273.3[c] (16.54)	272.3[b] (16.51)	251.3[c] (15.86)	141[c] (11.89)	137.5[d] (11.74)
10. Sadayanpallam	299.3[d] (17.31)	288.3[c] (16.99)	274.3[c] (16.57)	252.3[d] (15.89)	243.6[d] (15.62)	137.5[d] (11.74)	132.5[e] (11.53)

In a column, means superscripted by a common letter are not significantly different by DMRT (P = 0.05)
Values in parentheses are after square root transformation

Fig. 2. Flowering phenology and relative population levels of MFF in different mango orchard systems across 75 km from Thrissur to Tamil Nadu border during 2006-07



In Nenmara location, there was a medium level of population as observed from the second week of January, 2007 till April third week 2007. The peak population was obtained in April third week (16^{th} standard week of 2007 with 313.3 flies) and afterwards the population got slowly decreased.

Among the ten locations continuously observed for the fly population, the highest level of fruit fly population and the highest peak was observed in Kollengodu location with extensive mango orchards nearby. The highest peak was observed during the 16^{th} standard week of 2007 (April third week with 393.3 flies).

In Muthalamada, Nariparachella and Sadayanpallam locations, the MFF population was increasing starting from 2^{nd} standard week of 2007 (January second week) onwards and the peak population was observed during the 16^{th} standard week of 2007 (April 3^{rd} week) in all the three locations with 351, 344.3 and 341.6 flies respectively. After that the population was slowly reduced found declining.

4.9 RELATIVE SUSCEPTIBILITY OF MANGO VARIETIES TO MANGO FRUIT FLY INFESTATION

The results on the susceptibility of mango varieties to mango fruit fly infestation are given in Table 22.

Among the 10 varieties of mango fruits observed, Prior and Alphonso showed the maximum level of infestation of 46.6% each. This was followed by Olour (26%), Bangalora (16.6%), Banganapalli (16.6%), Kalapady (10%) and Neelam (6.6%). Among the local varieties, Moovandan was observed to be the least preferred one (6.6%) closely followed by Chandrakkaran and Vellaikolumban which showed 10 per cent infestation each. Chandrakkaran variety though showed oviposition puncture marks, it was not supporting any live maggots within the pulp, which indicated its strong antibiosis after the oviposition and hence found to be the least susceptible variety.

Table 22. Relative susceptibility of MFF infestation in different variety of mango at Vellanikkara during 2006-07

Sl.No.	Varieties	Total fruits	Infested fruits*	Percent infestation
1	Olour	30	8	26.6 (31.04)^{c}
2	Prior	30	14	46.6 (43.05)^{d}
3	Moovandan	30	2	6.6 (14.88)^{a}
4	Bangalora	30	5	16.6 (24.04)^{b}
5	Neelam	30	2	6.6 (14.88)^{a}
6	Kalapady	30	3	10.0 (18.43)^{a}
7	Chandrakaran	30	3	10.0 (18.43)^{a}
8	Banganapalli	30	5	16.6 (24.04)^{b}
9	Alphonsa	30	14	46.6 (43.05)^{d}
10	Vellaikolamban	30	3	10.0 (18.43)^{a}

* Infestation ascertained based on the oviposition punctures and confirmed fly maggot emergence with in the fruit pulp

In a column, means superscripted by a common letter are not significantly different by DMRT (P = 0.05)

Values in parentheses are after square root transformation

4.9.1 Relative susceptibility of mango fruit stages and other fruits to fruit fly infestation

Among the different stages of mango fruit development it was observed that fallen and ripened fruits were found to be with the maximum level of infestation (80%). The cracked fruits showed upto 46.6 per cent infestation. The ripened fruits had only a moderate level of damage (20%). The marble and lemon stage were the least infested stages of growth with lower number of oviposition punctures (Plates 29 to 30) with 6.6 per cent and 10 per cent respectively (Table 23).

The lemon and marble stages as well as cracked fruits were found to be more attracted by *B. dorsalis* whereas, the fallen and ripened fruits were found to be infested with both *B. dorsalis* and *B. correcta*.

The results on the per cent infestation and fruit fly species on different fruit crops were presented in Table 24.

Among the 14 types of different host fruits observed rose apple showed cent per cent infestation level and found to be the most susceptible one. This was followed by guava (30%), carambola (23.3%), banana (20%), sapota (20%), papaya (16.6%), jamun (13.3%), fig (13.3%), bread fruit (10%), bilimbi (10%) and lovi lovi (8.3%) (Plates 31 to 38).

From guava fruit, three fruit fly species were identified viz. *B. dorsalis*, *B. correcta* and *B. zonata*, while from ripened fig fruit only two species of fruit flies were identified viz. *B. dorsalis* and *B. zonata*. The *B. correcta* was identified in jamun fruit. Only one species viz., *B. dorsalis* could only be identified in sapota, rose apple, bread fruit, carombola, papaya, lovi lovi and bilimbi. There was no fruit fly infestation in passion fruit, karonda and *Garcinia* (kudampuli) fruits (Table 24).

Table 23. Relative susceptibility of MFF infestation to growth stages to mango and damaged fruits

Sl. No.	Stages	Total fruits	Infested fruits	Percent infestation	Species*
1	Marble stage	30	2	6.6^{a} (14.88)	*B. dorsalis*
2	Lemon stage	30	3	10^{b} (18.43)	*B. dorsalis*
3	Ripened fruit	30	6	20^{c} (26.56)	*B. dorsalis*
4	Cracked fruit	30	14	46.6^{d} (43.05)	*B. dorsalis*
5	Fallen ripened fruit	30	24	80^{e} (63.43)	*B. dorsalis*, *B. correcta*

* Species confirmation after adult rearing out from the host fruits

In a column, means superscripted by a common letter are not significantly different by DMRT (P = 0.05)

Values in parentheses are after arcsine transformation

Table 24. Relative susceptibility of different host fruits and species diversity of *Bactrocera* fruit flues during 2005-06 in the College orchard

Sl. No.	Name of the fruit	Total fruits	Infested fruits	Percent infestation	Species
1	Sapota	30	6	20^{d} (26.56)	*B. dorsalis*
2	Guava	30	9	30^{f} (33.21)	*B. dorsalis, B.zonata and B. correcta*
3	Fig	30	4	13.3^{b} (21.38)	*B. dorsalis* and *B.zonata*
4	Rose apple	60	60	100^{g} (90.00)	*B. dorsalis*
5	Banana	30	6	20^{d} (26.56)	*B. dorsalis*
6	Bread fruit	30	3	10^{a} (18.43)	*B. dorsalis*
7	Jamun	60	4	13.3^{b} (21.38)	*B. correcta*
8	Carambola	30	7	23.3^{e} (21.38)	*B. dorsalis*
9	Papaya	12	2	16.6^{c} (24.04)	*B. dorsalis*
10	Lovi lovi	60	5	8.3^{a} (16.74)	*B. dorsalis*
11	Blimbi	60	6	10^{a} (18.43)	*B. dorsalis*
12	Passion fruit	15	-	-	-
13	Karonda	30	-	-	-
14	Kudampuli	30	-	-	-

In a column, means superscripted by a common letter are not significantly different by DMRT (P = 0.05)

Values in parentheses are after arcsine transformation

Plate 29. Ovipunctures with fresh ooze after oviposition by *Bactrocera dorsalis* adult fly on mango fruit

Plate 30. Freshly oviposited eggs of *Bactrocera dorsalis* within the mango flesh torn open

Plate 31. Fruit fly ovipuncture and damage on rose apple by *Bactrocera dorsalis*

Plate 32. Ovipuncture on Jamun fruit by *Bactrocera correcta*

Plate 33. Ovipuncture on Guava fruit by *Bactrocera dorsalis*

Plate 34. Fruit fly maggot damage within the Guava fruit

Plate 35. Fruit fly damage and maggots on fig fruit by *Bactrocera dorsalis*

Plate 36. Ovipuncture on papaya fruit by *Bactrocera dorsalis*

Plate 37. Fruit fly damage on Bread fruit by *Bactrocera dorsalis*

Plate 38. Fruit fly damage and maggots on bread fruit

4.10 EFFICIENCY OF STICKY TRAP BOARDS FOR LURE TRAPPING THE FRUIT FLIES IN ORCHARDS

a) Efficacy of yellow sticky board trap against mango fruit fly in mango orchard

The results of yellow sticky traps against mango fruit fly lure trapping in mango are presented in Table 25.

The mean fruit fly catch on the yellow sticky traps, showed a significant difference among the sizes of the boards and the hanging positions. 30 cm x 20 cm sized vertical yellow sticky board trap gave the maximum fruit fly catch of 27.7 flies, while the same sized board in horizontal position recorded mean catch of 18.7 flies only. While comparing 30 cm x 10 cm horizontal board and 30 cm x 10 cm vertical board trap, it was found that the 30 cm x 10 cm horizontal sticky board trap had highest mean catch (17.4), where as 30 cm x 10 cm vertical trap had the least catch of 11.7 flies. The yellow sticky board trap of 20 cm x 10 cm size had the least mean catch of 5.3 flies only.

b) Efficacy of yellow sticky board trap against mango fruit fly in sapota orchard

The mean catch of fruit flies, showed a significant difference among the treatments (Table 26). The 30 cm x 20 cm vertical board trap showed a maximum mean catch of 22.3 flies while, 30 cm x 20 cm horizontal and 30 cm x 10 cm horizontal board traps recorded a mean catch of 15.8 and 12.4 flies respectively. The 30 cm x 10 cm vertical board trap and 20 cm x 10 cm traps had the least mean catch of 7.9 and 2.6 flies respectively. The 30 cm x 20 cm vertical board trap recorded significantly higher catches in all the observations, while all the other traps recorded the low fruit fly catches.

4.11 STICKY LURE SWABBING TECHNIQUE IN MANGO ORCHARDS AGAINST MANGO FRUIT FLY ENTRAPPING

a) Gelatin based sticky lure swabbing technique for male fruit fly entrapping in mango orchard

The mean catch of male fruit flies, showed a significant difference among the treatments (Table 27). The methyl eugenol swab showed a maximum mean catch of

Table 25. Performance evaluation of different yellow sticky lure traps against MFF in mango orchard

Size	Weekly mean FF catch*								Mean FF catch
	March 9/06	10/06	11/06	12/06	13/06	April 14/06	15/06	16/06	
1. 30 x 20 cm Horizontal	20[b] (4.52)	25.3[b] (5.07)	24.6[b] (5.0)	30[b] (5.52)	20.6[b] (4.59)	15[b] (3.93)	10[b] (3.24)	4.6[b] (2.25)	18.7[b] (4.38)
2. 30 x 20 cm Vertical	26[a] (5.14)	32[a] (5.70)	35.6[a] (6.0)	36.6[a] (6.09)	30.6[a] (5.57)	25.6[a] (15.10)	20.6[a] (4.59)	15[a] (3.93)	27.7[a] (5.31)
3. 30 x 10 cm Horizontal	15.6[c] (4.01)	20.6[c] (4.59)	25[b] (5.04)	26.6[c] (5.20)	21[b] (4.63)	15.6[b] (4.01)	10.6[c] (3.33)	4.6[b] (2.25)	17.4[b] (4.23)
4. 30 x 10 cm Vertical	11.3[d] (3.43)	14.3[d] (3.84)	15.6[c] (4.01)	21.3[d] (4.66)	15.3[c] (3.97)	10.6[c] (3.33)	4.3[d] (2.19)	1.6[c] (1.44)	11.7[c] (3.49)
5. 20 x 10 cm	5.3[e] (2.40)	7.3[e] (2.79)	9.3[d] (3.13)	11.6[e] (3.47)	7.3[d] (2.79)	3.6[d] (2.02)	2[d] (1.58)	1.3[c] (1.34)	5.9[d] (2.52)

* Mean of three observations

In a column, means superscripted by a common letter are not significantly different by DMRT (P = 0.05)

Values in parentheses are after square root transformation

Table 26. Performance evaluation of different yellow sticky lure traps against MFF in sapota orchard

Size	Weekly mean fruit fly catch*								Mean FF catch
	March 9/06	10/06	11/06	12/06	13/06	April 14/06	15/06	16/06	
1. 30 x 20 cm Horizontal	10[b] (3.24)	15.6[b] (4.01)	24.6[b] (5.0)	26[b] (5.14)	20.6[b] (4.59)	15[b] (3.93)	10[b] (3.24)	4.6[b] (2.25)	15.8[b] (4.03)
2. 30 x 20 cm Vertical	20.6[a] (4.59)	25.3[a] (5.07)	31.3[a] (5.63)	30.6[a] (5.57)	24.6[a] (5.0)	20.6[a] (4.59)	15.3[a] (3.97)	10.6[a] (3.33)	22.3[a] (4.77)
3. 30 x 10 cm Horizontal	10[b] (3.24)	15.6[b] (4.01)	20.6[b] (4.59)	20[c] (4.52)	15.6[c] (4.01)	10.6[c] (3.33)	4.6[c] (2.25)	2.3[c] (1.67)	12.4[c] (3.59)
4. 30 x 10 cm Vertical	5[c] (2.34)	10.6[c] (3.33)	15[c] (3.93)	14.3[d] (3.84)	11.3[d] (3.43)	4.6[d] (2.25)	2.3[d] (1.67)	0.6[d] (1.04)	7.9[d] (2.89)
5. 20 x 10 cm	2.3[d] (1.67)	3[d] (1.87)	6[d] (2.54)	4[e] (2.12)	3.3[e] (1.94)	1.3[e] (1.34)	1[d] (1.22)	0.3[d] (0.89)	2.6[e] (1.76)

* Mean of three observations

In a column, means superscripted by a common letter are not significantly different by DMRT (P = 0.05)

Values in parentheses are after square root transformation

Table 27. Male FF response to gelatin based sticky lure swabs on mango trees

Gelatin based lure swabs	Weekly mean catch												Mean FF catch
	Feb. 5/06	6/06	7/06	8/06	March 9/06	10/06	11/06	12/06	13/06	April 14/06	15/06	16/06	
1. ME + Jaggery	71^{c} (8.45)	90.3^{c} (9.52)	111^{c} (10.55)	121^{c} (11.02)	136^{c} (11.68)	136^{c} (11.68)	121^{c} (11.02)	100.6^{c} (10.05)	86.3^{c} (9.31)	66.3^{c} (8.17)	45.6^{c} (6.78)	25^{c} (5.04)	92.5^{c} (9.64)
2. ME + Banana	91^{b} (9.56)	110.3^{b} (10.52)	131^{b} (11.46)	142^{b} (11.93)	156^{b} (12.5)	156^{b} (12.5)	136.6^{b} (11.7)	112^{b} (10.6)	98^{b} (9.92)	76^{b} (8.74)	56^{b} (7.51)	40^{b} (6.36)	108.7^{b} (10.44)
3. PH + ME	2.6^{d} (1.76)	2.3^{d} (1.67)	4.6^{d} (2.25)	4.3^{d} (2.19)	6^{d} (2.54)	5.6^{d} (2.46)	7^{d} (2.73)	3^{d} (1.87)	1.3^{d} (1.34)	0.6^{d} (1.04)	0^{d} (0.71)	0^{d} (0.71)	3.1^{d} (1.89)
4. Ocimum	0.6^{d} (1.04)	1^{d} (1.22)	1^{d} (1.22)	2^{d} (1.58)	1^{e} (1.22)	2^{d} (1.58)	1.3^{e} (1.34)	1^{d} (1.22)	0.6^{d} (1.04)	0.3^{d} (0.89)	0.6^{d} (1.04)	0^{d} (0.71)	0.95^{e} (1.20)
5. ME	131.6^{a} (11.49)	152.6^{a} (12.37)	180.3^{a} (13.44)	210^{a} (14.5)	202.6^{a} (14.25)	224.6^{a} (15.0)	193.6^{a} (13.93)	179.3^{a} (13.4)	163.6^{a} (12.81)	143.3^{a} (11.99)	111.3^{a} (10.57)	101.6^{a} (10.10)	166.2^{a} (12.9)

In a column, means superscripted by a common letter are not significantly different by DMRT ($P = 0.05$)

Values in parentheses are after square root transformation

166.2 flies while, ME + jaggery and ME + banana (Plate 39 and 40) recorded 108.7 and 92.5 flies respectively. The protein hydrolysate + ME swab and ocimum macerate swab recorded the minimum mean number of flies catches with 3.1 and 0.95 flies respectively.

The ME swab recorded significantly higher catches in all the observations and it was attracting more male flies while, protein hydrolysate + ME and ocimum were the least effective ones in attracting the male flies.

b) Gelatin based sticky lure swabbing technique for female fruit fly entrapping in mango orchard

The mean catch of female fruit flies showed a significant difference among the treatments (Table 28). The ME + banana swab showed a mean maximum catch of 30.4 flies. This was followed by ME + jaggery, banana slurry and banana + jaggery swab with 20.2, 12.1 and 10.7 fly catches respectively. The swab based on jaggery and mango pulp had recorded the least mean catch with 5.6 and 2.3 flies respectively. The protein hydralysate swab recorded zero catch which was on par with control.

From the overall mean data over 12 weeks of observation it was found that the methyl eugenol swab ranked highest in the total male fly catch, while ME + banana swab ranked highest in the attraction of female fly catch.

4.11.1 Response of fruit fly species to different sticky lure swab attractants in mango orchard

The results on the efficacy of different attractants to fruit fly species in sticky lure swab treatments are presented in Table 29.

Methyl eugenol as gelatin swab was found to be attracting four fruit fly species viz., *B. dorsalis*, *B. caryeae*, *B. correcta* and *B. zonata*; where as banana slurry, ocimum macerate and banana + jaggery as slurry attracted two fruit fly species viz., *B. dorsalis* and *B. correcta*. The mango pulp attracted three species viz., *B. dorsalis*, *B. correcta* and *B. zonata*, while, jaggery solution attracted only, *B. dorsalis*.

Table 28. Female FF response to gelatin based sticky lure swabs on mango trees

Gelatin based lure swabs	Weekly mean catch												Mean FF catch
	Feb. 5/06	6/06	7/06	8/06	March 9/06	10/06	11/06	12/06	13/06	April 14/06	15/06	16/06	
1. ME + Jaggery	18.6^{b} (4.37)	22^{b} (4.74)	22.6^{b} (4.80)	27^{b} (5.24)	30.3^{b} (5.54)	27.6^{b} (5.3)	32.6^{a} (5.75)	26^{b} (5.14)	16.3^{b} (4.09)	11.3^{b} (3.43)	6.3^{b} (2.60)	2.6^{b} (1.76)	20.2^{b} (4.54)
2. ME + Banana	30.6^{a} (5.57)	36^{a} (6.04)	41^{a} (6.44)	42.6^{a} (6.56)	45.3^{a} (6.76)	46.6^{a} (6.86)	35.6^{a} (6.0)	31^{a} (5.61)	25.6^{a} (5.1)	14.6^{a} (3.88)	10.6^{a} (3.33)	5.3^{a} (2.40)	30.4^{a} (5.55)
3. PH	0^{e} (0.71)	0^{g} (0.71)	0^{e} (0.71)	0^{e} (0.71)	0^{f} (0.71)	0^{f} (0.71)	0^{e} (0.71)	0^{f} (0.71)	0^{f} (0.71)	0^{e} (0.71)	0^{d} (0.71)	0^{d} (0.71)	0^{g} (0.71)
4. Jaggery	2.6^{d} (1.76)	5^{e} (2.34)	5^{d} (2.34)	4^{d} (2.12)	8.3^{d} (2.96)	11.3^{d} (3.43)	13.3^{c} (3.71)	9.3^{d} (3.13)	5^{d} (2.34)	2.3^{d} (1.67)	1.3^{d} (1.34)	0.6^{cd} (1.04)	5.6^{e} (2.46)
5. Banana + Jaggery	7^{c} (2.73)	9.6^{d} (3.17)	10.6^{c} (3.33)	15.3^{c} (3.97)	16.6^{c} (4.13)	17.6^{c} (4.25)	18.3^{d} (4.33)	15^{c} (3.93)	11.3^{c} (3.43)	5.3^{c} (2.40)	1.6^{d} (1.44)	0.6^{cd} (1.04)	10.7^{d} (3.34)
6. Mango pulp	1.3^{d} (1.34)	3^{f} (1.87)	3^{d} (1.87)	4^{d} (2.12)	3.6^{e} (2.02)	4^{e} (2.12)	3.6^{d} (2.02)	2.3^{e} (1.67)	1.3^{e} (1.34)	1^{d} (1.22)	0.6^{d} (1.04)	0.3^{cd} (0.89)	2.3^{f} (1.67)
7. Banana slurry	9.3^{c} (3.13)	14^{c} (3.80)	13^{c} (3.67)	16.6^{c} (4.13)	18^{c} (4.3)	20^{c} (4.52)	19.6^{b} (4.48)	15.3^{c} (3.97)	9.6^{c} (3.17)	6^{c} (2.54)	3.3^{c} (1.94)	1.3^{c} (1.34)	12.1^{c} (3.54)
8. Control	0^{e} (0.71)	0^{g} (0.71)	0^{e} (0.71)	0^{e} (0.71)	0^{f} (0.71)	0^{f} (0.71)	0^{e} (0.71)	0^{f} (0.71)	0^{f} (0.71)	0^{e} (0.71)	0^{d} (0.71)	0^{d} (0.71)	0^{g} (0.71)

In a column, means superscripted by a common letter are not significantly different by DMRT (P = 0.05)

Values in parentheses are after square root transformation

Table 29. Species diversity response to gelatin based sticky lure swabs in mango during non rainy periods

Sl. No.	Treatments (gelatin based lure swabs)	*Bactrocera spp.* attracted
1	Methyl eugenol	*B. dorsalis, B. correcta, B.zonata, B.caryeae*
2	Banana slurry	*B. dorsalis* and *B. correcta*
3	Jaggery solution	*B. dorsalis*
4	Banana + Jaggery	*B. dorsalis, B. correcta*
5	Ocimum	*B. dorsalis, B. correcta*
6	Mango pulp	*B. dorsalis, B. correcta, B.zonata*

Plate 39. Fruit flies on sticky lure swab trap on mango tree trunk

Plate 40. Dead fruit flies on sticky lure swab trap in mango orchard

4.11.2 Efficacy of different sticky lure swabs on the fruit damage by *B. dorsalis* on mango

The results on the per cent fruit damage (Table 30) showed a significant difference among the treatments in reducing the mango fruit fly infestation where observed for oviposition marks on the fruits.

The ME + banana swab was found to be the best treatment with only 3.33 per cent infestation. This was followed by methyl eugenol (4.99%) and ME + jaggery (7.21%). The infestation was maximum in protein hydralysate giving 31.66 per cent damage, which was found to be on par with control.

4.12 EFFICACY OF BIORATIONAL APPROACHES IN FRUIT FLY *B. dorsalis* MANAGEMENT IN MANGO ORCHARD

Field Trial I

The results of the field experiment in mango var. Prior conducted in the College orchard at Vellanikkara, Thrissur district during December 2005-06 are presented in Table 31.

The per cent fruit damage obtained from the field experimentation significantly differed among the treatments at harvests. The methyl eugenol bottle traps were statistically superior to all other treatments with the least mean percentage damage of fruits with 2.9 per cent. This was followed by malathion cover spray (8.8% damage) and banana + jaggery trap (12.9% damage). The highest mean damage of 36.6 per cent was recorded in the untreated check.

Field Experiment II

The results of the field experiment in var. Alphonso conducted in the college orchard at Vellanikkara during December 2005-06 are furnished in Table 32.

The per cent fruit damage ranged from 3.3 (Methyl eugenol trap) to 33.3 per cent (untreated check) at harvest. Malathion cover spray and banana + jaggery trap were

Table 30. Lure swabbing techniques and FF infestation in mangoes

Sl. No.	Lure treatments	Per cent FF damage		Mean % FF damage
		Ist harvest*	IInd harvest*	
1	ME + Jaggery	7.77 (16.18)^{b}	6.66 (14.95)^{b}	7.21 (15.57)^{c}
2	ME + Banana	3.33 (10.51)^{a}	3.33 (10.51)^{a}	3.33 (10.51)^{a}
3	Protein Hydralysate	31.11 (33.90)^{e}	32.22 (34.58)^{e}	31.66 (34.24)^{h}
4	PH + ME	28.88 (32.50)^{e}	31.11 (33.90)^{e}	29.99 (33.20)^{g}
5	Jaggery	20.00 (26.56)^{d}	18.88 (25.75)	19.44 (26.16)^{f}
6	Banana + Jaggery	13.33 (21.41)^{c}	12.22 (20.46)^{c}	12.77 (20.93)^{d}
7	Mango pulp	17.77 (24.93)^{d}	17.77 (24.93)^{d}	17.77 (24.93)^{e}
8	Ocimum	28.88 (32.50)^{e}	31.11 (33.90)^{e}	29.99 (33.20)^{g}
9	Methyl eugenol	5.55 (13.62)^{ab}	4.44 (12.16)^{a}	4.99 (12.90)^{b}
10	Banana	12.22 (20.46)^{c}	13.33 (21.41)^{c}	12.77 (20.93)^{d}
11	Control	31.11 (33.90)^{e}	32.22 (34.58)^{e}	31.66 (34.24)^{h}

* Mean of 90 fruits selected at random from the harvested lot

In a column, means superscripted by a common letter are not significantly different by DMRT (P = 0.05)

Values in parentheses are after arcsine transformation

Table 31. Bio efficacy of attractants and food lures techniques against *B. dorsalis* damage in mango var. Prior (December 2005-06)

Sl. No.	Treatments	Mean per cent damage*			Mean % damage
		First harvest	Second harvest	Third harvest	
1	Methyl eugenol trap	3.3 [a] (10.46)	3.3 [a] (10.46)	2.2 [a] (8.52)	2.9 [a] (9.80)
2	PH bait spray	16.6 [e] (24.04)	18.8 [de] (25.69)	26.6 [e] (31.04)	20.6 [f] (26.99)
3	Banana + Jaggery trap	10.0 [c] (18.43)	13.3 [c] (21.38)	15.5 [c] (23.18)	12.9 [c] (21.04)
4	Yeast autalysate bait trap	13.3 [d] (21.38)	16.6 [d] (24.04)	20.0 [d] (26.56)	16.6 [e] (24.04)
5	Fishmeal + Pine apple trap	16.6 [e] (24.04)	20.0 [e] (26.56)	25.5 [e] (30.32)	20.7 [f] (27.06)
6	Ocimum trap	16.6 [e] (24.04)	20.0 [e] (26.56)	26.6 [e] (31.04)	21.0 [f] (27.27)
7	Mango powder	10.0 [c] (18.43)	13.3 [c] (21.38)	16.6 [c] (24.04)	13.3 [d] (21.38)
8	Malathion	6.66 [b] (14.95)	6.66 [b] (14.95)	13.3 [b] (21.38)	8.8 [b] (17.25)
9	Control	33.3 [f] (32.24)	33.3 [f] (32.24)	43.3 [f] (41.14)	36.6 [g] (37.22)

* From 30 fruits selected at random per replication from the harvested lot of a trees

In a column, means superscripted by a common letter are not significantly different by DMRT (P = 0.05)

Values in parentheses are after arcsine transformation

Table 32. Bio efficacy of attractants and food lures techniques against *B. dorsalis* damage in mango var. Alphonso mango (December 2005-06)

Sl. No.	Treatments	Mean per cent damage*
1	Methyl eugenol trap	3.3 (10.46)[a]
2	Protein Hydralysate bait spray	13.3 (21.38)[d]
3	Banana + Jaggery trap	6.6 (14.88)[b]
4	Yeast autalysate bait trap	13.3 (21.38)[d]
5	Fishmeal + Pine apple trap	20.0 (26.56)[f]
6	Ocimum trap	16.6 (24.04)[e]
7	Mango powder	10.0 (18.43)[c]
8	Malathion	6.6 (14.88)[b]
9	Control	33.3 (32.24)[g]

* Mean of 30 fruits selected at random per replication from harvested lot of a trees
In a column, means superscripted by a common letter are not significantly different by DMRT (P = 0.05)
Values in parentheses are after arcsine transformation

on par with each other in reducing the fruit fly infestation and recorded a damage of 6.6 per cent each in both the cases. Mango powder and yeast autolysate as bait traps had only moderate level of damage with 10.0 and 13.3 per cent respectively. The ocimum trap and protein hydrolysate recorded higher fruit damage showing their low efficacy (16.6 and 13.3% damage respectively).

Field experiment III

The results of the field experiment in Prior conducted in the college orchard at Vellanikkara during December 2006-07 are presented in Table 33.

The mean percent fruit damage ranged from 3.3 per cent (Methyl eugenol bottle trap and ME + banana sticky lure swab) to 34.4 per cent (untreated check). The ME bottle trap and ME + banana sticky lure swab were found to be the best treatments with only 3.33 per cent infestation level. This is followed by ME + banana as bait spray with 6.0 per cent damage and malathion cover spray with 7.1 per cent damage. The infestation was moderately low in the banana + jaggery bait trap with 10.5 per cent damage which was on par with *Spathiphyllum* trap plants (10.5%). The untreated control plot recorded a damage as high as 34.4 per cent.

The results on mango fruit yield (Table 34) revealed that ME + banana swab trap recorded the highest yield (10,022 kg/ha) followed by methyl eugenol trap (10,005 kg/ha) and malathion (10,000 kg/ha). The lowest yield (9,501 kg/ha) was observed in the untreated check. The marginal increase in fruit yield over untreated check was in the order of 5.48, 5.30 and 5.25 per cent, in the treatments ME + banana swab trap, methyl eugenol trap and malation.

Methyl eugenol bottle trap gave the highest net profit of Rs. 8573/ha followed by ME + banana swab trap (Rs. 7847/ha) and malathion (Rs. 6940/ha). The lowest profit of Rs. 1195/ha was obtained in fallen fruit sanitation.

Table 33. Bioefficacy of attractant and food lure techniques against mango fruit fly (*B. dorsalis*) damage in mango var. Prior (December 2006-07)

Sl. No.	Treatments	Mean per cent damage*		Total mean % damage
		First harvest	Second harvest	
1	Methyl eugenol trap	3.3 (10.46)[a]	3.3 (10.46)[a]	3.3 (10.46)[a]
2	Banana + Jaggery trap	10.0 (18.43)[c]	11.1 (19.46)[c]	10.5 (18.90)[c]
3	Yeast autalysate bait trap	16.6 (24.04)[e]	16.6 (24.04)[e]	16.6 (24.04)[e]
4	ME + Banana swab trap	3.3 (10.46)[a]	3.3 (10.46)[a]	3.3 (10.46)[a]
5	ME + Banana bait spray	6.6 (14.88)[b]	5.5 (13.56)[b]	6.0 (14.17)[b]
6	Fruit destruction	13.3 (21.38)[d]	13.3 (21.38)[d]	13.3 (21.38)[d]
7	Soil treatment	13.3 (21.38)[d]	15.5 (23.18)[e]	14.4 (22.3)[d]
8	Malathion	6.6 (14.88)[b]	7.7 (16.11)[b]	7.1 (15.45)[b]
9	*Spathiphyllum* plants	10.1 (18.53)[c]	11.0 (19.36)[c]	10.5 (18.90)[c]
10	Control	33.3 (32.24)[f]	35.5 (36.57)[f]	34.4 (35.91)[f]

* Per cent mean of 30 fruits per replication selected at random from the harvested lot of 4 trees each

In a column, means superscripted by a common letter are not significantly different by DMRT (P = 0.05)

Values in parentheses are after arcsine transformation

Table 34. Economics of the biorational approaches in the management of mango fruit fly in mango

Sl. No.	Treatments	Fruit yield (kg/ha)	% increase over untreated check	Increased yield over untreated check (kg)	Value of increased yield/ha (Rs. 20/kg)	Cost of labour and insecticide/ha)	Net profit (Rs.)	Benefit cost ratio (BCR)
1	Methyl eugenol trap	10005	5.30	504	10080	1507	8573	5.68:1
2	Banana + Jaggery trap	9850	3.67	349	6980	1852	5128	2.76:1
3	Yeast autalysate bait trap	9652	1.58	151	3020	1576	1444	0.91:1
4	ME + Banana swab trap	10022	5.48	521	10420	2573	7847	3.04:1
5	ME + Banana bait spray	9952	4.74	451	9020	2502	6518	2.60:1
6	Fallen fruit sanitation	9647	1.53	146	2920	1725	1195	0.69:1
7	Soil treatment	9645	1.51	144	2880	1534	1346	0.87:1
8	Malathion	10000	5.25	499	9980	3040	6940	2.28:1
9	*Spathiphyllum* plants	9843	3.59	342	6840	2017	4823	2.39:1
10	Control	9501	-	-	-	-	-	-

The results on benefit cost ratio revealed that methyl eugenol bottle trap recorded highest ratio of 5.68:1 followed by ME + banana swab trap (3.04:1). The banana + jaggery trap, ME + banana bait spray, *Spathiphyllum* trap plants and malathion also recorded a substantially better benefit cost ratios of 2.76:1, 2.60:1, 2.39:1 and 2.28:1 respectively.

4.13 POST HARVEST DISINFESTATION OF MFF OVIPOSITED FRUITS BY HOT WATER TREATMENT

The mature fruits after harvest were subjected to sorting into infested and uninfested fruits. The infested fruits identified based on the black coloured oviposition marks were subjected to hot brine treatment at four concentration of common salt and few levels of time exposures.

Among the different combinations of salt concentration and time intervals, it was found that (Table 35) 0.5 per cent brine at 15 minutes dip treatment gave cent per cent kill of the oviposited eggs and maggots within the fruit. The treatment with 0.5 per cent salt concentration for 30 minutes also gave cent per cent kill of the infested eggs and maggots without affecting the quality of the fruits. Higher temperature (45 minutes) and higher salt concentrations (2% and 3%) recorded cent per cent kill of the infested stage within the fruits but were expressing qualitative losses in terms of shrinkage and faded colour. However, one minute dip at all concentrations were ineffective (44.44 - 11.11%) in destroying the eggs and maggots when observed after post harvest storage and ripening.

4.14 FIELD SURVEY ON THE NATURAL ENEMIES OF *B. dorsalis*

Parasitoid

The data on the present and prevalence of natural enemies reared out from the host stages within field collected and infested mango fruits are presented in Table 36. Only one species larval pupal parasitoid was obtained during the study period and was identified in the department as *Biosteres arisanus* (Sonan) (Hymenoptera: Braconidae) (Plates 41 and 42). During the period of observation the highest percentage

Table 35. Effect of post harvest technique against latent damage of MFF on mango var. Alphonso with oviposition marks

Salt concentrations \ Time intervals	Mean per cent damage*			
	One min	15 min	30 min	45 min
0.5%	44.44[a] (41.80)	0	0	0
1%	22.22[b] (28.12)	0	0	0
2%	11.11[c] (19.47)	0	0	0
3%	11.11[c] (19.47)	0	0	0

*Mean of three replications with 9 fruits each after 3-5 days of ripening after treatment

In a column, means superscripted by a common letter are not significantly different by DMRT (P = 0.05)

Values in parentheses are after arcsine transformation

Table 36. Mean per cent parasitism of *Biosteres arisanus* from the pupae of MFF, *B. dorsalis* during eclosion

Months	Total number of pupae of *B. dorsalis*	Number of parasitoids ecloded from the *B. dorsalis* pupae	Mean percentage parasitism
March 2006	182	2	1.09 [c] (1.26)
April 2006	253	7	2.76 [a] (1.80)
May 2006	201	4	1.99 [b] (1.57)
March 2007	195	1	0.51 [d] (1.00)
April 2007	254	7	2.76 [a] (1.80)
May 2007	223	3	1.34 [c] (1.35)

In a column, means superscripted by a common letter are not significantly different by DMRT (P = 0.05)

Values in parentheses are after square root transformation

Plate 41. Adult female of the larval-pupal parasitoid, *Biosteres arisanus* (Sonan)

Plate 42. Adult female of *Biosteres arisanus* (Sonan) alighted on the infested mango fruit

parasitisation of the MFF pupae recorded was only 2.76 during the months of April during both 2006 and 2007. The lowest parasitization of 0.5 per cent was recorded during March 2007.

Predator

Weekly survey conducted in the mango fields during the fruiting season at Vellanikkara recorded only one predator viz., the red ant, *Oecophylla smaragdina* (Fabricius) found to be devouring on the dead mango fruit fly adults only and there was no direct evidence of its predation on the live maggots within the infested and fallen fruits.

Discussion

5. DISCUSSION

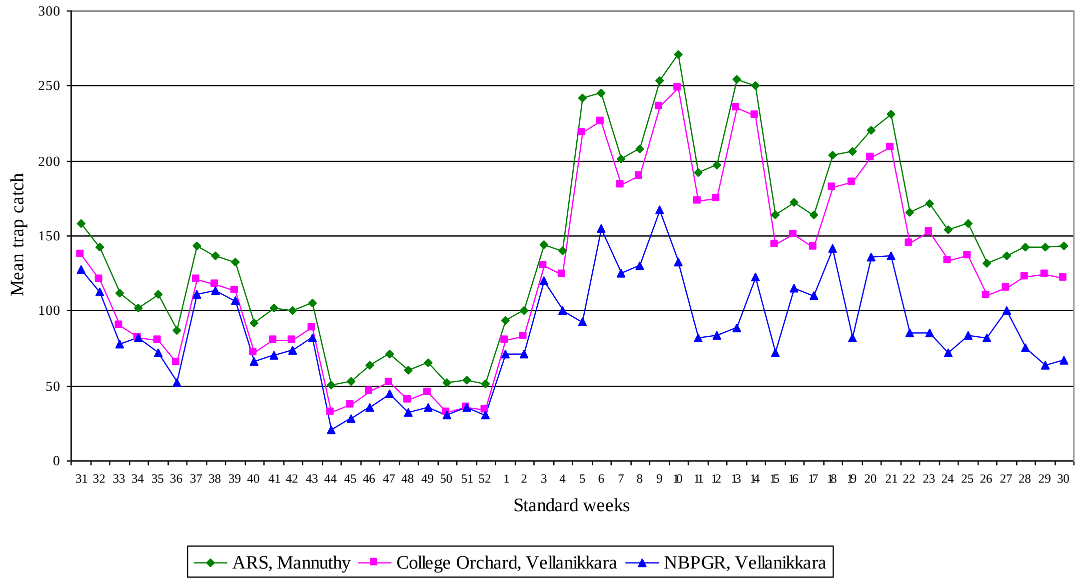
The results obtained from the laboratory and field experimentation on the "Species diversity of the orchard fruit fly complex and the biorational management of the mango fruit fly (MFF) *Bactrocera dorsalis*" are discussed in this chapter to elucidate the various observations, detections and findings.

5.1 POPULATION DYNAMICS OF FRUIT FLIES AT VELLANIKKARA-MANNUTHY REGIONS

The results of the studies on the population dynamics of MFF conducted from August 2005 to July 2006 (i.e. from 31st standard week of 2005 to 30th standard week of 2006) in three locations at Vellanikkara and Mannuthy regions revealed that the population reached the first peak by February first week and thereafter maintained a higher population load till fourth week of May. However, the traps recorded lower catches during the entire November and December months. The highest peak was recorded during the second week of March 2006 (10th standard week) and the lowest during second week of December (50th standard week) (Fig. 3). As different fruits served as hosts for the *Bactrocera dorsalis* complex viz., sapota, lovi lovi, citrus, fig, guava, carambola and jack, their population reached several lesser peaks as and when the fruits were available in plenty. In some fruit crops the population was having two to three peaks in an year synchronized with the frequency of flowering and fruiting as well as with the higher precipitation in the environment and high temperature.

Gupta and Bhatia (2001) observed two population peaks of *B. dorsalis* catch during 27th and 30th standard weeks in mango orchard and 37th and 39th standard weeks in guava orchard in the sub montane region of Himachal Pradesh, in North India. However, the peak catches of *B. dorsalis* recorded were during 21st, 23rd and 46th standard weeks in mango orchards in the Karnataka down South India (Babu and Viraktamath, 2003b). Suhail *et al.* (2000) observed that the highest male population of *Dacus* spp. was in the first week of July. Verghese and Devi (1998) reported that, trap catches were higher during the months of May to August in Bangalore. Mann (1996) also observed that the population counts were very low in the winter months from

Fig. 3. Population dynamics of fruit fly complex in mango orchard systems at three locations in Thrissur during August 2005 to July 2006



December to February and high during July. Khattak *et al.* (1990) also observed that, peak population of *B. dorsalis* was reached in July and thereafter declined from August-November and there was no activity during December. Kawashita *et al.* (2004) noted that, *B. correcta* was found in traps by using methyl eugenol from October to February and *B. zonata* was from April to July. Jalaluddin *et al.* (2001) studied the population fluctuations of the guava fruit fly *B. correcta* in July to August. Qureshi *et al.* (1991) observed that adult fly populations were at their peak during fruit maturation in June. Zaman (1995) observed the peak abundance of *B. dorsalis* during July in peach and apricot orchards. Agarwal *et al.* (1999b) also recorded the peak population of peach fruit fly *B. zonata* during the third week of June. The highest fruit fly population observed in guava orchard, in China was during July-November (HaiDong *et al.* 1995). Hui and Ye (2001) reported that peak abundance of oriental fruit fly was from June in Jinghong to October in Yiaoan.

From these earlier reports and from our present investigation, it was evident that the population build up and abundance of *B. dorsalis* was location specific, and varies with other factors such as crop density, presence of heavy weeds in orchards, alternate host, fruit ripening stage, harvesting time(late harvest), fallen fruits, cracked and diseased fruits, crowded leaves, more number of fruiting periods in an year in different fruit crops, shady conditions, elevation, wind direction, honey dew and heavy rain followed by two to three sunny days at harvesting time etc. Fletcher (1987) therefore, suggested that weather parameters and available hosts play a vital role in the population build up of tephritid fruit flies. Since these deciding factors vary with different locations and crops, the population peaks also differ accordingly with respect to the fruit fly populations.

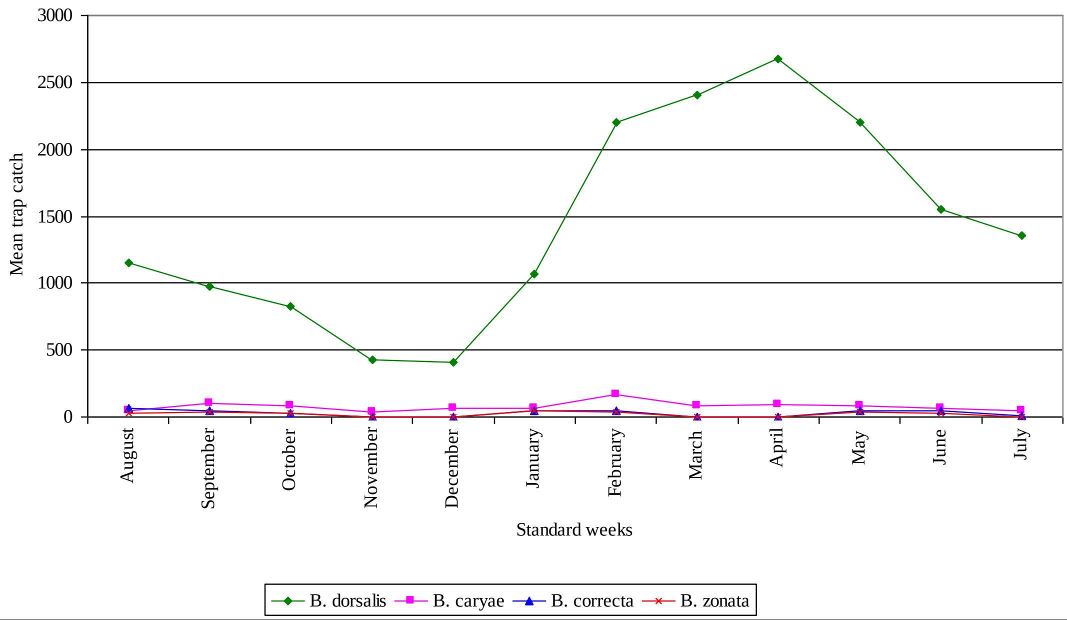
In the present study, the correlation between fruit fly catch and weather parameters revealed that, the maximum temperature (r = 0.525) and minimum temperature (r = 0.305) have significant positive correlation with the trap catch in mango. Among other fruit crops, rainfall also showed a positive correlation with fruit fly population in sapota. In lovi lovi, the maximum and minimum temperatures and relative humidity showed a significant positive correlation with trap catch while, in citrus, minimum temperature alone and in jack maximum and minimum temperatures increased the fruit fly catch positively. In guava, fig and carambola, all the weather parameters showed a non significant correlation with the fruit fly population because of the staggered flowering, fruiting and uncared orchard sanitation on the fallen fruits.

Babu and Viraktamath (2003b) observed that *B. zonata* and *B. correcta* population had significant correlation with temperature, while, *B. dorsalis* and *B. cucurbitae* populations had non significant correlation with weather parameters (including RH and rainfall). However, Verghese and Devi (1998) reported that *B. dorsalis* trap catches showed a significant positive correlation with minimum temperature and wind speed. According to Agarwal *et al.* (1995), population dynamics of *B. dorsalis* recorded significant positive correlation with maximum and minimum temperatures. A study conducted by Jalaluddin *et al.* (2001) also revealed that population of *B. correcta* showed a significant positive correlation with maximum temperature, minimum temperature, day-degrees, morning relative humidity and rainfall.

Based on earlier reports and from present investigation, it was evident that the population build up and abundance of *B. dorsalis* was location and crop specific and which indicated the importance of the South West monsoon season characterized by the high temperature in Kerala during non rainy days. The micro-weather parameters vary with one crop to another as it is influenced by plant architecture, the nature of crowded leaves and canopy spread. Since these are the deciding factors that vary with different crops, systems and locations, the population peaks are also found to differ accordingly.

The results of the monthly population trap catches (Fig. 4) conducted from August 2005 to July 2006 revealed that there were four species of fruit flies viz., *B. dorsalis, B. caryeae, B. correcta* and *B. zonata* which were responding to methyl eugenol at Vellanikkara. Among these orchard fruit flies, *B. zonata* was rarely reported in Kerala as this is a North Indian species as reported from Bengal and referred to as "Peach fruit fly" due to its more attack on peach fruits (Kapoor, 1993).

Fig. 4. Monthly population dynamics and diversity of Bactrocera species in mango orchard at Vellanikkara during August 2005 to July 2006



Metcalf (1990) had reported that there are at least 58 species of fruit flies belonging to the subfamily Dacinae found to be attracted to methyl eugenol world wide. The present study revealed that the number of fruit flies responding to methyl eugenol at Vellanikkara was considerably low as it was evident from the species richness index (S) with a value of only four.

The species diversity indices viz., Simpson-Yule Diversity Index (D) with a value of 1.38 (scale 1 to 4) and Shannon-Weaver Diversity Index (H) with a value 0.58 (scale 0 to 1.38), clearly indicated a low level of species diversity in *Bactrocera* genus with a very few dominant species which were adapted to the specific environmental conditions in the experimental area.

A low value obtained from Shannon-Weaver evenness index (E) also showed that the species present in the community have varying number of individuals with an uneven distribution. The Berger-Parker dominance index (d) also revealed that *B. dorsalis* was the dominant species among the different orchard fruit fly species responding to methyl eugenol at Vellanikkara, with a high value of 0.96 and therefore we should concentrate on this dominant species for its economic management and the other lesser dominant species for just subject monitoring only.

In the population studies, the methyl eugenol bottle traps provided an easy and efficient method to monitor the fruit fly populations. However, it attracts only male flies and there is no direct evidence on the abundance of female flies, which actually cause the economic damage. Hence, laboratory studies undertaken to assess the sex ratio relationship of mango fruit flies during their respective periods in different fruiting seasons enable the prediction of female catches based on the sex ratio parameters. The results revealed that the sex ratios determined were 1:0.99, 1:0.86, 1:0.97, 1:0.94 and 1:1.06 on different fruits of mango, bread fruit, rose apple, fig and guava respectively, indicating a male dominance in all the fruits except guava with an unusual female dominance. The male dominance may be due to the summer effect and the female dominance due to the moisture effect during the rainy seasons especially in Kerala conditions. But, the ratios were not found significantly different from the normal 1:1 ratio, indicating that trap catch of male flies could be taken as a indirect indicator for the assumption of female fruit fly population in the field. Further, suitable correction factors based on the actual sex ratios in different fruit crops in the respective fruiting seasons, could be worked out to calculate a more precise prediction of the female fly abundance. Rameash (2006) and Bhagat *et al.* (1998) after studying the seasonal variation in the sex ratios of melon fly reported that, the ratios obtained during different seasons were not significantly different from the normal 1:1 ratio in conformity with the present results.

5.2 DETERMINATION OF OPTIMUM EXPOSURE HEIGHT FOR THE DISPENSATION APPLICATION OF ME BOTTLE TRAPS AND STICKY LURE SWAB TRAPS IN ORCHARD FRUIT CROPS

The experimental results revealed that, two meter height proved to be the best with optimum fruit fly catches in both rainy and non rainy periods in mango orchards while exposing the ME bottle traps (Fig. 5 and 6) for monitoring and lure trapping purposes.

Sticky lure swab application in mango and bread fruit (Fig. 7 and 8) also revealed that the two meter height proved to be the best for catching maximum number of flies as compared to either below or above heights. In sapota (Fig. 9), 1.5 metre height application caught more number of flies. With respect to the directional orientation of attraction in the swab application, the Western side of the trunk attracted more number of the flies followed by that in the South, North and Eastern sides. It proves that the flies emerged during the morning hours prefer to take shelter and hide on the Western and Southern sides against the light from the eastern side of the tree trunks. However, Sarada *et al.* (2001) reported that the ME bottle traps placed on the ground caught significantly more number of flies followed by that at 1.0 m, 2.0 m and 1.5 m respectively in mango orchard.

Based on earlier report and present investigation, it is evident that, the optimum height for fruit fly attraction was at two metres which may vary with the geometry of the plant canopy and the architecture of the plant types. In non rainy days,

Fig. 5. Trapping heights and fruit fly catch in ME bottle traps on mango trees during rainy season

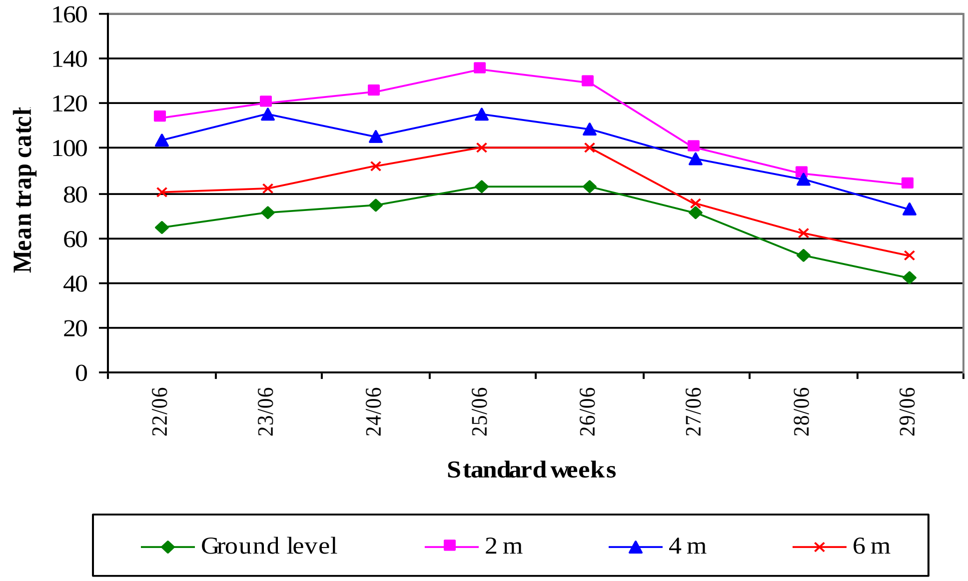


Fig. 6. Trapping heights and fluit fly catch in ME bottle traps on mango trees during non rainy season

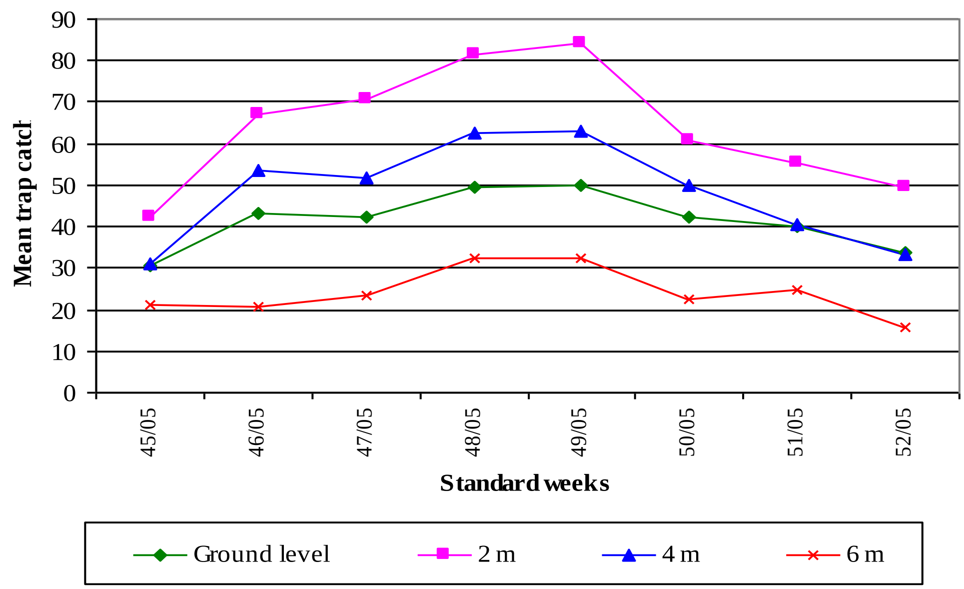


Fig. 7. Trapping heights and directional orientation of MFF to sticky lure swabs in mango tree

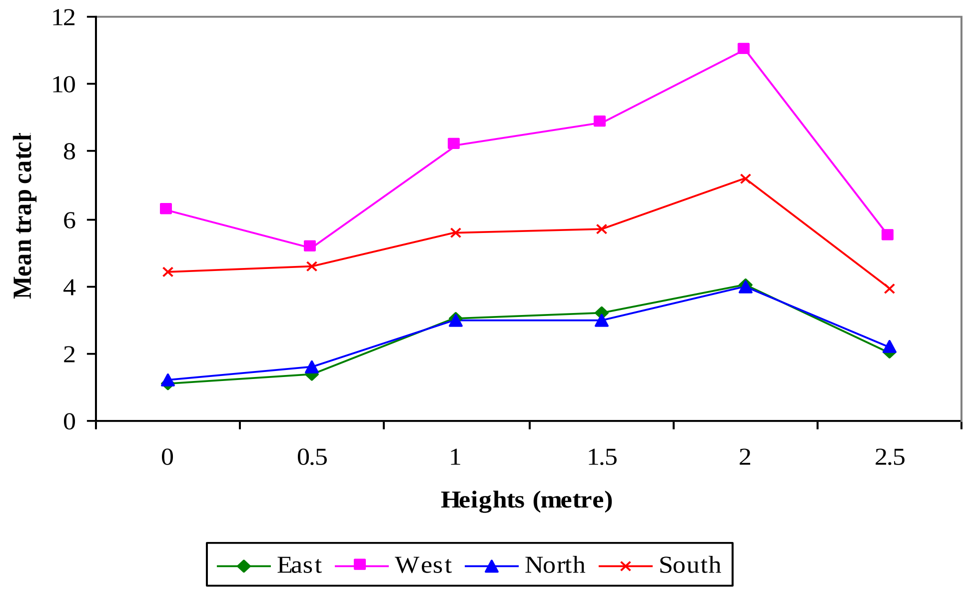
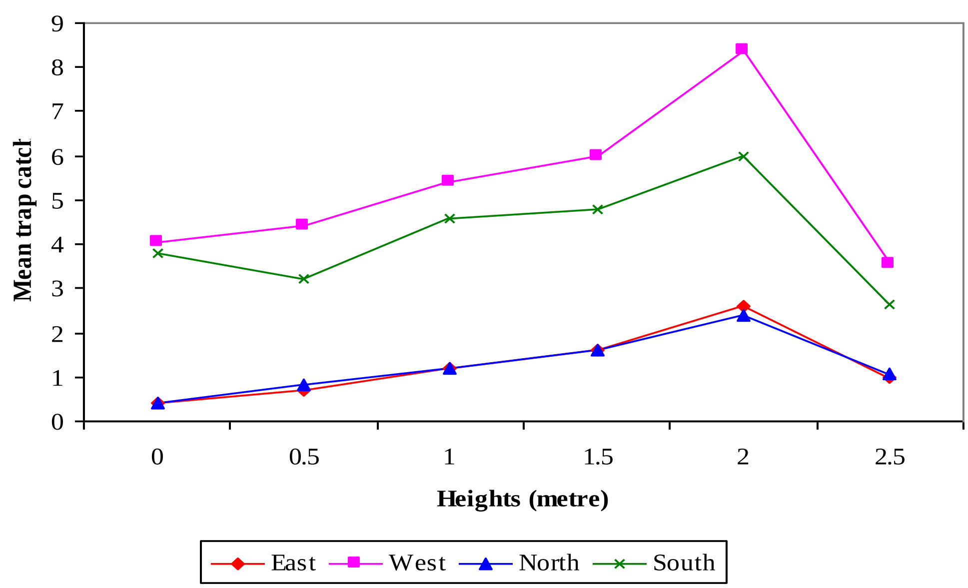


Fig. 8. Trapping heights and directional orientation of MFF to sticky lure swabs in bread fruit



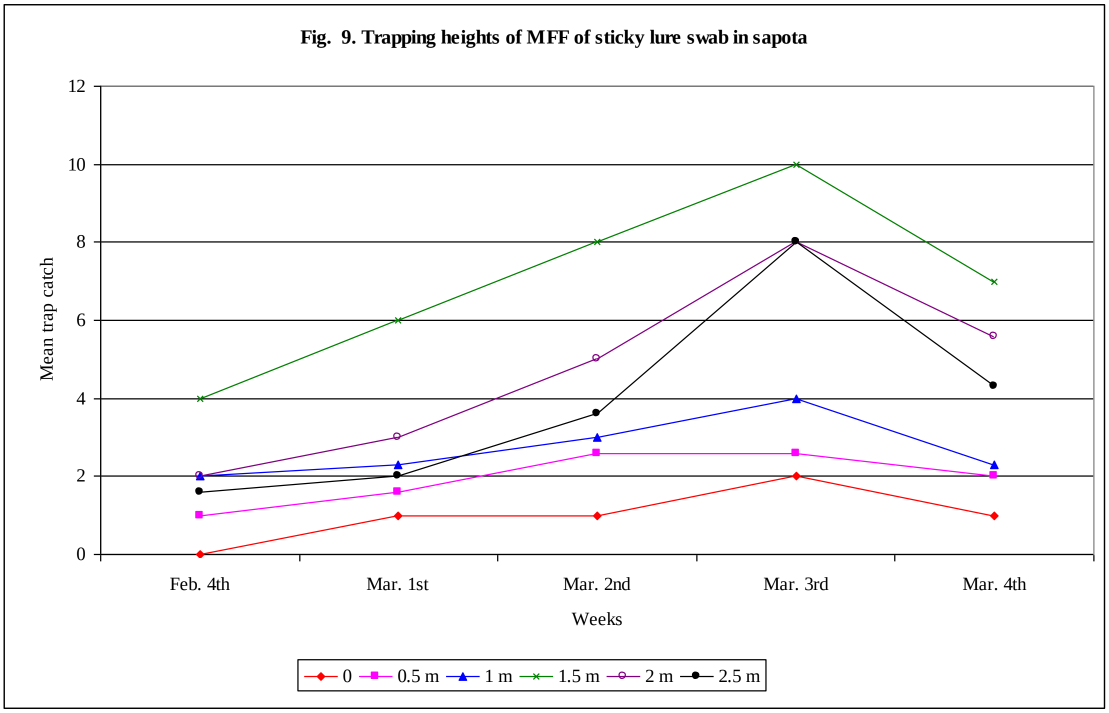


Fig. 9. Trapping heights of MFF of sticky lure swab in sapota
12
10
8
6
4
2
0
Mean trap catch
Feb. 4th
Mar. 1st
Mar. 2nd
Mar. 3rd
Mar. 4th
Weeks
0
0.5 m
1 m
1.5 m
2 m
2.5 m

after emergence from the soil, the fruit fly adults escape from the ground and reach upon the lower canopy of the trees. Thus, the lower canopy of the fruit crops hosted with more number of fruit flies and thereby being attracted to traps and swabs at the same level.

As with the optimum height of attraction (2 m), the Western sides of the tree trunk attracted more number of fruit flies. It may be due to the more shades available in the Western side as against the Eastern light when compared to the other directions. However, during off season in mango, the fruit flies could be located in all the four sides of the trunk as they might be coming from other host fruit crops in the nearby areas as the generation individuals.

5.3 EFFICACY OF *SPATHIPHYLLUM* AS A TRAP PLANT FOR MFF MANAGEMENT

It was observed that *Spathiphyllum* inflorescence attracted maximum number of mango fruit flies around 7 to 8 am. It was also observed that the inflorescence (spadix) was actively attracting the fruit flies for more than 19 days. More flies were found to be attracted to the milky white colour stage of the spadix than the green colour matured spadix. It may be due to presence of methyl eugenol content expressed in the spadix which might be more in the milky white colour stage than in the mature green spadix. Chuah *et al.* (1996) had identified four attractant principles for the males of *B. dorsalis* viz. trans-3, 4-dimethoxy cinnamyl alcohol, trans-3, 4-dimethoxy cinnamyl acetate, P-methoxy benzyl alcohol and 3,4-dimethoxy benzyl alcohol. The common attractants identified are eugenol and methyl eugenol from the head of the spadix of *S. cannaefolium* is in conformity with the present results.

5.4 BEHAVIOURAL ECOLOGY OF *B. dorsalis* IN MANGO

5.4.1 Alightment and hiding behaviour at flushing and fruiting time

Understanding the identification of alightment and hiding behaviour of MFF on mango trees is very important for their management and the results revealed that underside of leaves in the lower canopy of the tree were having the maximum number of adult fruit flies after their eclosion from the soil during the flushing season. The proximal end of fruits with lower canopy of the tree are colonized with more number of fruit flies during fruiting period. It might be due to the escape mechanism from the over exposure of sunlight on the mango trees which facilitate them for successful congregation and eventual courtship and mating activities. The fruit flies always preferred shady lower areas than the top of the tree. As the apical portion of mango tree is exposed to direct sunlight, fruit flies colonize and hide under the lower canopy leading to successful mating and oviposition on the fruits damaging them more than that in the fruits in the upper canopy. Because of this behavioural ecology the cover spray application as well as bait traps and bait application should be undertaken in the lower canopy only in managing the fruit fly which would avoid over use and misappropriate application of pesticidal inputs.

5.4.2 Emergence rhythm of mango fruit fly in mango orchard

In the population studies, the ME traps provide an easy and efficient method to monitor the male fruit fly populations in their adult stages, but there is no direct evidence to monitor female fruit flies as they are not responding to para pheromones like ME. Hence the emergence studies were undertaken to assess the emergence pattern and rhythm of both male and female flies from the substrate of both soil and fallen fruit which indicated the time, direction and intensity of emergence of the fruit fly adults.

The results revealed that the maximum emergence of mango fruit flies were from the soil basin at 2-3 m radial distance around the trunk followed by the peripheral ground area of the canopy shade. It was also found that more number of adult fly emergence was observed from the North-Eastern side of the tree base. The peak time of adult flies emergence from the soil litter was determined between 6 to 7 am and with no emergence detected in the afternoon hours.

The middle canopy of the mango tree carried more number fruits than the periphery of the canopy cover and hence the relative infestation and consequent shedding of fruits were more experienced in the middle area of the ground base under the canopy shade. So we can expect more number of fallen fruits and with more number of flies emerging out from the middle zone of the tree base. As with the direction of fly emergence, more shedding of fruits were actually observed in the North Eastern side of the mango trees and consequently increased pupation of the fly maggots and adult emergence in these sides. Therefore, the pupae were also more in the North-Eastern side which resulted in higher rate of pupal emergence from these sides as recorded from the emergence trap studies. The peak time of adult emergence observed at 6 to 7 am, might be due to the favorable micro climate with low temperature, high humidity and optimum soil moisture in the soil during early morning hours.

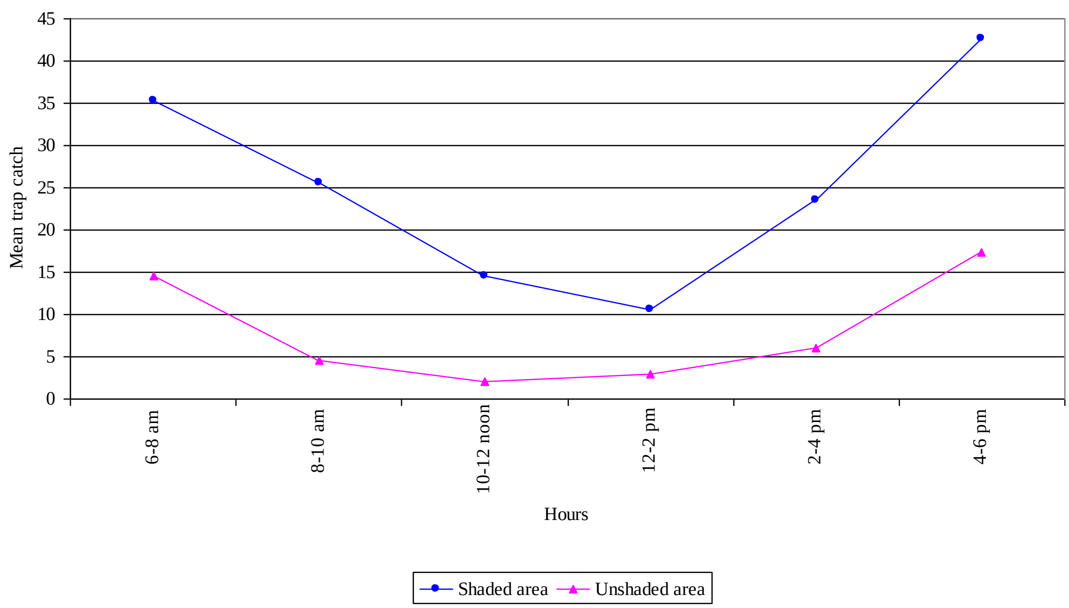
5.4.3 Diurnal response of fruit flies to methyl eugenol traps under shaded and unshaded conditions

The results revealed that the peak hour of attraction of fruit flies to ME bottle trap was found to be between 4-6 pm and between 6-8 am under the shaded canopy of mango tree. It proved that the adult flies are having more crepuscular behaviour. This might be due to the fact that, fruit flies were more active and preferential to shady and low temperature conditions. Jayanti and Verghese (1998) also observed the hourly fluctuations in trap catches (baited with ME + carbaryl) of *B. dorsalis* in a mango orchard and found that the catches were maximum in the afternoon, with a peak time between 16.00 and 17.00 hours which is in conformity with the present results. The very low catch of fruit flies observed at 6-8 am under open air conditions (Fig. 10) again proved that the flies were preferring shady and low temperature conditions to open aid situations. Therefore it could be inferred that the fruit fly traps should be installed under shade on the tree canopy for optimum catch efficiency.

5.5 VARIETAL RESPONSE OF MANGO AND OTHER HOST FRUITS TO FRUIT FLY INFESTATIONS

Among different mango varieties observed, the varieties viz., Prior and Alphonso were found to be having the maximum level of maggot infestations.

Fig. 10. Diurnal response of MFF to ME traps under shaded and unshaded exposures in the orchard



Neelam, Muvandan and Chandrakaran were the least preferred ones. Eventhough, oviposition punctures were visible in these three varieties, the fruit was not supporting any live maggots within the pulp, which indicated the strong antibiosis of these varieties after the oviposition. The heavy infestation in Prior and Alphonso might be due to their thin and soft skin, strong odour, high sugar content and light green colour of the fruit.

Among the different stages of growth and condition of mango fruits observed, the ripe fruits that are cracked, and fallen were found to be with the higher level of infestations ranging from 46.6 to 80 per cent. The strong odour from the damaged and ripened fruits as well as the broken rind might have invited more flies for oviposition and consequent higher damages by the maggots.

Among the other host fruits, rose apple and ripened guava had recorded higher infestations as high as 100 per cent and 30 per cent respectively. It might be due to more softness, sugar content, strong odour and the preferred colour (yellow for guava and white for rose apple which might be more attractive characters for the fruit flies) as well as due to the off season for the more preferred mango fruits. In other fruit crops such as sapota, fig, cracked banana, bread fruit, jamun, carambola, papaya, lovi lovi and bilimbi infestations were caused by the *B. dorsalis* complex at varying levels depending upon above influencing fruit and environmental characteristics.

Among the fruit fly species identified, guava hosted more number of *Bactrocera* spp. viz., *B. dorsalis*, *B. zonata* and *B. correcta* while, jamun hosted *B. correcta* only. All other fruits hosted only *B. dorsalis*. Therefore, it could be inferred that the *B. dorsalis* is the dominant species because of the polyphagous nature of infestation on different host fruits. This observation could be corroborated with the ecological parameters found out already by Berger-Parker Dominance Index (d) value of 0.96.

5.6 EVALUATION OF FOOD LURES TO MFF BY SKP STUDIES IN CAGES

Evaluation on the performances of food lures in the fruit fly attraction and orientation under SKP cage experimentation enabled the natural performance of the MFF under ideally uniform conditions whose results are discussed below.

The results of the SKP studies revealed that among different banana macerates evaluated, robusta and poovan were found to be attracting more number of *B. dorsalis* flies both in terms of faster orientation and total numbers attracted as against the more attraction of palayankodan variety to the melon fly *B. cucurbitae* (Thomas, 2005). Among the cut pieces of fruits tested, Prior mango and rose apple were showing more performance in terms of speedy response and total number of MFF orientation. As with banana macerates, the pulp texture, sugar content, the odour and the sliminess might be the influential factors for increased attraction of fruit flies. In the case of fruit pieces, softness, colour, sugar and odour might be the parameters that attracted more number of flies to the fruit substrates.

5.7 SPATIAL DISTRIBUTION AND SPREAD OF MANGO FRUIT FLY INFESTATION IN DIFFERENT GEOGRAPHICAL LOCATIONS

Generally, dispersion of insects from one place to another is for shelter, food, and oviposition based on the host phenology in fruit crops. Ros *et al.* (1999) reported that the cooler localities were affected by the migration of flies (*C. capitata*) coming from the warmer localities, on temperate fruit crops. Flowering of the mango trees is observed early in the season in the dry zone tracts of Tamil Nadu - Kerala border areas followed by that in the transitional areas of Muthalamada region and towards in the season in the humid areas of Thrissur tracts. Consequently the fruiting and ripening phases were also found staggered along with the fruit fly damage in the localities as evidenced by the population level in the ME bottle traps. Depending upon the flowering and fruiting as well as the time the relative catches of MFF in the ME traps, it is evident that there is the concomitant trend of change in the fly population and fruit damage there no probability of any suspected migration across these areas. Hence the fruit fly population level is strictly in accordance with flowering and fruiting of the mango fruits in the different tracts.

5.8 EFFICIENCY OF YELLOW STICKY BOARDS FOR FRUIT FLY MONITORING IN MANGO AND SAPOTA ORCHARDS

The common types of traps used in capturing Indian fruit flies are Steiner type trap, G-K collapsible trap, sticky boards and McPhail trap. Among the different traps, the sticky boards are cheaper, easy to be assembled and transported. They were good for detection purposes (especially for quarantine aspects) around airports and towns as reported by Kapoor (1993). So, these traps were evaluated for its efficiency against fruit fly monitoring in orchard crops viz, mango and sapota systems at Vellanikkara.

The results of yellow sticky boards based on the attractant lure base with methyl eugenol + banana + gelatin macerate mix conducted in mango and sapota orchard system revealed that the yellow coloured vertically hanged, fibre board of polypack material of size 30 cm x 20 cm was optimum in its efficiency for the MFF monitoring and detection purposes (Fig. 11 and 12) as evidenced by the number of entrapped fruit flies with a mean number of 27.7 flies per trap per week.

Robacker and Heath (2001) made a sticky trap for fruit flies made from fruit fly adhesive paper (FFAP) covered with a plastic mesh of either 1.5 x 1.5 cm or 2.2 x 2.2 cm size and was found as effective as pherocon AM traps in capturing Mexican fruit flies (*Anastrepha ludens*). Khater *et al.* (1996) also observed that the yellow sticky trap was more effective in attracting adult males than females, and mostly during periods of low temperature and high relative humidity. Stark and Vargas (1992) reported that the white and yellow traps caught the highest number of flies, whereas green, red and black caught lesser numbers in plastic bucket traps.

Based on earlier reports and present investigation, it was evident that the yellow coloured sticky traps attracted more male flies and methyl eugenol + banana +

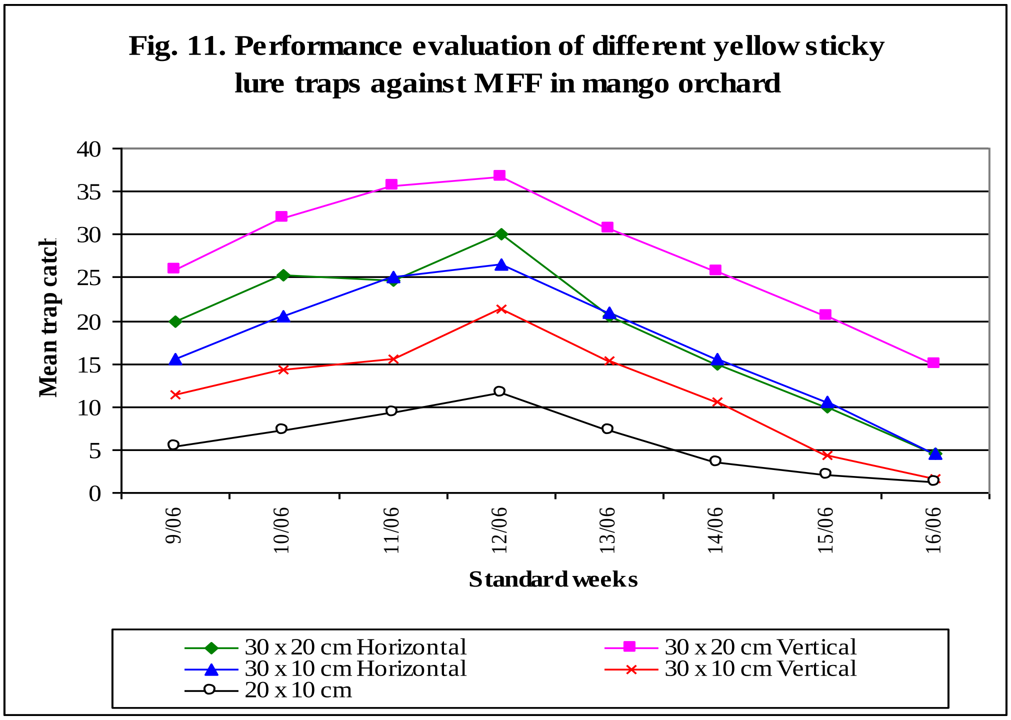


Fig. 11. Performance evaluation of different yellow sticky lure traps against MFF in mango orchard
Mean trap catch
Standard weeks
9/06
10/06
11/06
12/06
13/06
14/06
15/06
16/06
30 x 20 cm Horizontal
30 x 20 cm Vertical
30 x 10 cm Horizontal
30 x 10 cm Vertical
20 x 10 cm

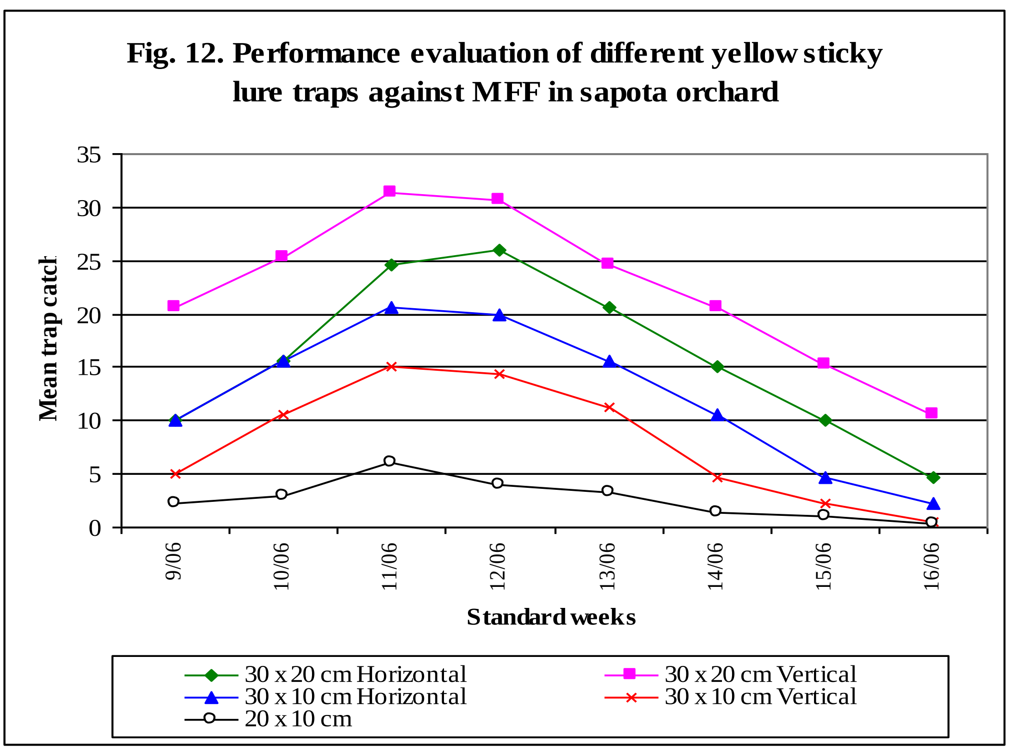


Fig. 12. Performance evaluation of different yellow sticky lure traps against MFF in sapota orchard
Mean trap catch
Standard weeks
9/06
10/06
11/06
12/06
13/06
14/06
15/06
16/06
30 x 20 cm Horizontal
30 x 20 cm Vertical
30 x 10 cm Horizontal
30 x 10 cm Vertical
20 x 10 cm

gelatin macerate based yellow sticky trap attracted both male and female flies together for longer periods which would offer a more realistic population prediction.

5.9 EFFICACY OF STICKY LURE SWABBING TECHNIQUE ON MANGO TRUNKS FOR MFF MONITORING AND ANNIHILATION

The tephritid flies have long since been recognized as sensitive to attractants like parapheronomones and food lures. The approaches like utilizing attractants either in trapping devices or as bait applications had been successfully demonstrated in the management of fruit flies world wide (Kapoor, 1993). However, in order to reduce the cost of application an innovative approach of sticky lure swab application was developed and evaluated as an effective IPM component.

Hence, the field experiment was conducted in mango orchard and evaluated the efficacy of gelatin based sticky lure swabs with methyl eugenol and food lure combinations. The results on the sticky lure swabs are discussed hereunder.

The sticky lure swab technique (Fig. 13 and 14) revealed that there was a significant difference in catch efficiency of the female MFF. The methyl eugenol + banana slurry mixture as a swab treatment on the trunk was trapping more number of female flies which might be more efficient and economically productive as compared to the male annihilation effect of the ME alone.

The methyl eugenol swab and ME + banana swab showed maximum catch while, ME + jaggery swab and banana + jaggery swab recorded only moderate catches. Banana, jaggery, mango pulp and ocimum lures recorded lower catches individually while, protein hydrolysate swab was recorded almost zero catch.

The results of different attractants against fruit flies revealed that, the methyl eugenol attracts more number species of male fruit flies (Four spp. of *B. dorsalis* complex) than the other treatments. Therefore ME sticky lure swabs can be explocited for efficient monitoring of fruit fly species complex.

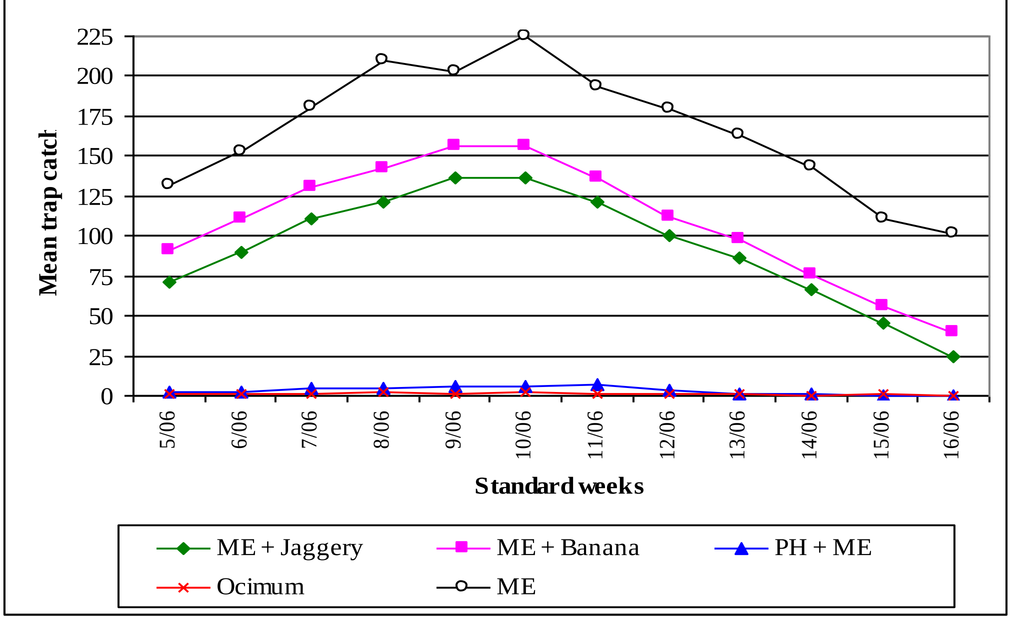


Fig. 13. Male FF response to gelatin based sticky lure swabs on mango trees

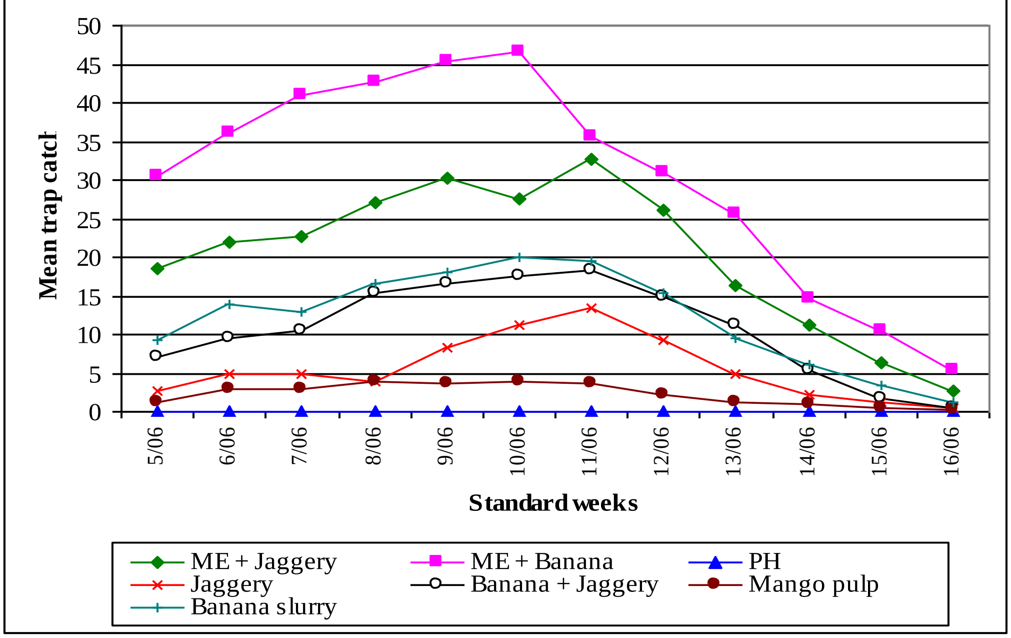


Fig. 14. Female FF response to gelatin based sticky lure swabs on mango trees

Howlett (1912) reported that male flies of *B. zonata* was attracted to methyl eugenol. Verghese (1998) noted that the methyl eugenol, as a bait for male tephritids, was also found to be attracting a small number of females of *B. dorsalis* during the active breeding time in a mango orchard at Bangalore. Chu *et al.* (1996) observed that no female flies were attracted to methyl eugenol, but a total of 300 males were entrapped. Males of *B. dorsalis* were attracted to the methyl eugenol baited traps from May to October during 1985 to 1986 (Zaman, 1995). Cornelius *et al.* (2001) found that methyl eugenol was an extremely effective attractant for male oriental fruit flies of *B. dorsalis*. Thomas *et al.* (2005) also observed that there was reduction in the infestation in mangoes by fruit flies after using ME blocks by 21%, ocimum leaf traps by 15%, banana traps by 12% and protein hydrolysate by 0%.

Dwivedi *et al.* (2002) found that maximum number of fruit fly adults of *B. dorsalis* was entrapped by methyl eugenol followed by jaggery. Roomi *et al.* (1993) reported that the *Ocimum sanctum* was found to be a potent attractant for luring and trapping *D. ciliatus, B. zonatus, B. dorsalis* and *B. cucurbitae* from a distance of 0.8 km in orchards in Pakistan.

In the present study also, the results indicated that the methyl eugenol attracted more number of male population as well as more number of fly species and consequently with low damage on the mango fruits. ME + banana swab was used for the first time in Kerala in mango orchard against mango fruit flies, which was efficient in attracting more female flies also with the lowest fruit damage because of the higher annihilation rate of female flies as comparable to the male annihilation rate of ME alone.

5.10 BIOEFFICACY OF BIRATIONAL APPROACHES IN THE MANAGEMENT OF *B. dorsalis* IN MANGO

Three orchard experiments viz. two number in Prior variety and one in Alphonso variety were undertaken to evaluate the efficacy of selected biorational approaches against mango fruit fly by bait and lure trapping technology.

The results of the orchard trial in mango variety Prior in the College farm revealed that the lowest fruit damage (3.3%) was observed with the methyl eugenol bottle trap. The banana-jaggery trap, malathion cover spray and mango powder trap recorded moderate levels of damage and the ocimum trap, fish meal + pineapple trap, yeast autolysate bait trap and protein hydrolysate bait spray resulted in significantly higher fruit damage. A similar trend was observed in the field trail II with Alphonso variety in the same orchard.

The results of field trial III in Prior mango variety again revealed that, the percent fruit damage was the lowest at 3.3 per cent with the methyl eugenol traps again. Malathion and ME + banana swab trap recorded moderate level of damage. The banana + jaggery trap, fallen fruit destruction and soil cover spray also recorded a low level of damage. However, Thomas *et al.* (2005) reported that the infestation reduction in mangoes by fruit flies with the use of ME blocks by 21%, ocimum leaf traps by 15%, banana traps by 12% and protein hydrolysate by 0%. Makhmoor and Singh (1997) also recorded that the fruit fly control of *B. dorsalis* was higher with 1% methyl eugenol trap in guava orchards.

These results proved that the male attracting ME bottle traps could reduce the fertile female fruit flies of *B. dorsalis* that could positively reduce the female oviposition and consequent damage on the fruits. So the male annihilation technique by ME bottle traps could be of better option for the fruit fly management. The banana slurry and the ME mix combination could also result in moderate damage levels by both annihilating the male population along with the female flies into the food lure base with banana. This method positively avoided the cover spray application of insecticides and there by achieving ecological sanctity in the management of *B. dorsalis* complex. Generally it could be seen that the lure swab treatments on the mango tree trunk applied along with gelatin as a sticker is more user friendly, low cost and efficient as compared to the bottle traps utilizing different lure materials. Protein hydrolysate as such is not found to be having any added effect upon the attraction of fruit flies and thereby produced no effect up on the reduction of damage level. Based on earlier reports, it was evident that methyl eugenol bottle trap as well as sticky lure swab application controlled the fruit flies with a low level of fruit damage and with low cost with a higher benefit cost ratio..

5.11 POST HARVEST DISINFESTATION OF MANGO AGAINST FRUIT FLY DAMAGE

The post harvest processing by hot water treatment in mango against mango fruit fly infestation is widely recognized as an efficient method for better quality mangoes for export. Better efficacy was achieved by modifying the hot water treatment with salt. The results of hot brine treatment in mango revealed that a 15 minutes dip at 50°C to 55°C with 0.5 per cent salt water was giving good control or cent per cent mortality of eggs which would prevent the potential latent infestation by the fly maggot and reduced the post storage loss by MFF.

Liang *et al.* (1993) earlier had reported that the mango fruits when immersed in water at 40°C for 20 min, followed by a 10 min dip at 46°C immediately brought the inside fruit temperature to 46°C to bring the mortality of the eggs and larvae to cent per cent. Grove *et al.* (1997) also reported that most of the fruit varieties immersed in water at 46.1°C for 90 minutes and refrigerated for 24 hours afterwards were not damaged and were found suitable for export. Smith (1992) also observed that the mango fruit needed immersion in water at 48°C for up to 90 minutes to control the eggs and final instar larvae of *Bactrocera aquilonis* in Australia.

Hot water treatment has been widely found efficient in post harvest disinfestation of diseases through the physical injuries during harvest by different workers. Under this pretext, the attempts made on disinfestation of the already oviposited mangoes with MFF just after harvest was undertaken with hot brine at 0.5 per cent level at 55°C for 15 minutes. It was then found to be efficient in destroying the eggs as well as the emerging maggots during ripening under storage. This technique was found to be offering cent per cent protection to the fruits damaged by an oviposition injury and latent post storage loss. Therefore, after harvest we have to sort out mangoes with oviposition marks and get them treated by this post harvest hot brine dip in preventing the loss by 44% that is not otherwise prevented and therefore an added bonus advantage for the farming community.

The hot water brine at 0.5 per cent and 55°C is able to disinfest fungal diseases and fruit rot normally experienced during post harvest storage. The temperature of hot water and time intervals should be adjusted with respect to the variety of the fruits depending upon the thickness of the rind and flesh. Thicker skin mango cultivars require more time and temperature where as soft skin cultivars require less time to control the eggs and maggots. The time interval for disinfestation of oviposition injury for the Alphonso variety with soft rind and flesh was determined to be 15 minutes at 0.5 per cent hot brine at 55°C and was optimum in maintaining the quality as well as preventing the latent fruit fly damage during storage.

5.12 FIELD SURVEY ON THE NATURAL ENEMIES OF *B. dorsalis*

A larval-pupal parasitoid, *Biosteres arisanus* (Sonan) was identified in the mango fruit fly at Vellanikkara whose level of maximum parasitisation was recorded to be 2.76 per cent. The *B. arisanus* has been reported to be the most important natural enemy in *B. dorsalis* in many parts of the world (Bautista *et al.*, 1998; Harris and Bautista, 1996; Vargas *et al.*, 1991).

The parasitic potential was already demonstrated by *Fopius arisanus* from Asia, which caused over 95 per cent egg mortality of the oriental fruit fly *B. dorsalis* in guava (Messing, 2003). Hence, it could be substantiated that the natural parasitisation levels of *B. arisanus* on mango fruit fly vary with respect to the host fly, systems of cultivation and locality and therefore studies should be initiated to strengthen the biocontrol value of this parasitoid under Kerala conditions by different conservation and augmentation further.

In the present study one general predator, red ant, *Oecophylla smaragdina* was observed in the mango orchard, without any direct confirmation of its predation on live stages of orchard fly but they were observed to be feeding on the entrapped adult flies in the ME bottle traps. Therefore the presence of red ants would be reducing the efficacy of ME bottle traps. However, Rajapakse (2000) had opined that the use of neem based products along with predatory ants *O. smaragdina* gave an excellent control of melon fly in cucurbitaceous crops.

Generally, predators had little effect on fruit fly population because of their biological behaviour of the life stages viz., egg, maggot and pupae that are not exposed to the outside environment but remain within the host fruits as well as in the soil substrate. However, there is a report by Williard (1927) who found that the big headed ants, *Pheidole megacephala* were feeding upon the maggots of *C. capitata* that were leaving the fallen fruits for pupation in the soil. Wong *et al.* (1984) also observed the predation by the Argentine ant, *Iridomyrmex humilis* on the final instar maggots of *C. capitata* that were falling on the ground for pupation and recorded a larval mortality of 3.9 per cent due to predation in peach gardens. However none of such effective predators would be observed in the orchards against mango fruit flies in the farm orchards both on the host tree as well as in the soil litter below.

Summary

6. SUMMARY

The study entitled, "Species diversity of the orchard fruit fly complex, and the biorational management of the mango fruit fly, *Bactrocera dorsalis* (Hendel) (Diptera : Tephritidae)" was carried out in the Department of Agricultural Entomology, College of Horticulture at Vellanikkara during 2005-07. Investigations were undertaken to study the population dynamics of orchard fruit flies and to correlate its seasonal occurrence with the weather parameters. Different types of lures and luring techniques were evaluated for both fruit fly monitoring as well as its management under field conditions. The emergence pattern of Mango fruit fly, its location and alightment on the host tree, optimum height of exposure of lure trapping, seasonal, spread and prevalence etc. of fruit flies were also evaluated. Different food lures were tested for their efficacy against fruit fly attraction was also undertaken. Finally, a package of eco-friendly and biorational management strategy against *B. dorsalis* in mango orchard was evolved and proposed for field application. The salient findings of the study are summarized below:

1. The population of orchard fruit fly species responding to methyl eugenol was monitored at weekly intervals from August 2005 to July 2006 at three locations in the university farm, NBPGR orchard at Vellanikkara and Mannuthy regions. It was revealed that there were four peaks of the fruit fly population with the first peak realised by February first week and thereafter with the higher population trend maintained upto the fourth week of May. The population showed lesser trap catches during the entire November and December months. During the entire annual observation, the highest peak was recorded during the second week of March and with the lowest during the second week of December. Different fruits were found serving as hosts for the *B. dorsalis* complex, such as sapota, lovi lovi, citrus, fig, guava, carambola and jack, their population showed several lesser peaks as and when these fruits were available in plenty.

2. Correlations between the fruit fly catch (in mango) and the weather parameters at Vellanikkara revealed that the maximum and minimum temperatures showed a significant positive correlation with the fly population. In other fruit crops, rainfall showed a positive correlation with the fruit fly population viz., in sapota. In Lovi lovi, maximum and minimum temperatures as well as relative humidity showed positive correlation with the fruit fly population. In jack fruit, both maximum and minimum temperatures increased the catch of the fruit flies. However, in guava, fig and carambola, all the weather parameters showed a non significant correlation with the fruit fly population.

3. The population of mango fruit fly species responding to methyl eugenol when monitored at monthly intervals from August 2005 to July 2006 revealed four species viz., *B. dorsalis, B. caryeae, B. correcta* and *B. zonata* from the trap catches.

4. The average monthly trap catches of *B. dorsalis, B. caryeae, B. correcta* and *B. zonata* were 1436.41, 77.83, 27.25, 19.33 flies/trap respectively. The species diversity index worked out revealed that the mango fruit fly, *B. dorsalis* is the most dominant species among the four as represented by its dominance value of 0.96.

5. Sex ratio studies revealed that *B. dorsalis* population in ripe mango, bread fruit, rose apple and fig were more male biased with a ratio of 1:0.99, 1:0.89, 1:0.97, 1:0.94 respectively, while it was a female dominant (1:1.06) in guava. However, the ratio analysis and chi-square test revealed that this ratios are non significantly different from the normal 1:1 ratio in all the fruit crops in their respective seasons.

6. Two metre was proved to be the optimum exposure height for fruit fly lure trapping with the ME bottle traps for both its monitoring and management in both rainy and non rainy periods in mango orchards.

7. The optimum height for the sticky lure swab application in mango and bread fruit was found to be again at two meter height while, in sapota, it was at 1.5 metre height with the maximum number of entrapped flies. Among the four directions of attraction, the Western and Southern sides on the trunk were entrapping with more number of flies than the other directions and thus the swab might be applied in these two directions for optimum trapping at Vellanikkara region and conditions.

8. The emergence rate of mango fruit flies from the ground soil was recorded to be higher from the middle zone of the basin ranging a radial distance range of 2-3 metres from the tree base which prompts the cultural practice of basin raking in this middle zone range of 2-3 m radial distance around the tree. The peak time of emergence of MFF from the soil basin was between 6 am to 7 am which warrants the lure trapping technique to be installed or refreshed before these hours for maximum catch efficiency.

9. The *Spathiphyllum* plants acting as a fruit fly trap plant was found to be expressing maximum floral attraction between 7 to 8 am and hence MFF removal trapping during these hours might be practiced for the reduction of the male population in the field.

10. The undersurface of the leaves in the lower canopy was found to be having the maximum number of alightment and hiding of the MFF adults and therefore the cover spray application of bait material and insecticide mixtures, if applied might be targeted only to the lower canopy of branches instead of any whole tree cover spray. The proximal end of the fruits in the lower canopy was having the higher mean number of fruit flies alighting for oviposition during fruit maturity.

11. Among different banana fruit macerates tested, varieties Poovan and Robusta were found to be with maximum fruit fly attraction and orientation under the SKP cage experimentation. Among the different fruit varieties tested, Prior

variety of mango and rose apple were found to be the highest responding food lures to lure fruit fly.

12. The peak hour of attraction of male fruit flies to ME bottle trap was determined to be between 4 to 6 pm and 6 to 8 am under shaded conditions and hence the installation of lure traps in mango orchards should be synchronized with these two timings for better trapping efficiency.

13. Spread and prevalence of mango fruit flies were based on the flowering and fruiting phenology of the mango trees. It was in the order of early flowering tracts to late flowering tracts as proved from the MFF catches over an ecological distance of 75 km from the Tamil Nadu boarder to Thrissur. The MFF population was having an increasing trend from the early flowering zone of Muthalamada regions to the late flowering zones of Thrissur regions.

14. Among the different mango varieties observed, the Prior and Alphonso were found to be having the maximum level of infestation, while, Neelam, Muvandan and Chandrakaran were the least preferred varieties. Among the other host fruits, Rose apple and ripened guava recorded the higher infestation rates as high as 100 per cent and 30 per cent respectively.

15. The yellow sticky trap lures in mango and sapota orchards revealed that the yellow poly pack board of size 30 x 20 cm in a vertically hanging position recorded the maximum number of fruit flies and therefore could be used for monitoring the MFF.

16. Sticky lure swab with ME and its combinations with food lures revealed that the methyl eugenol swab alone attracts more male flies while, methyl eugenol + banana slurry swab attracts more female flies.

17. Among different attractants tested against fruit flies revealed that, the sticky lure swab formulation with methyl eugenol attracted more number of fruit fly species than the other treatments.

18. Field experiments undertaken to evaluate the efficacy of selected biorational approaches against mango fruit fly in Mango variety Prior and Alphonso in the College orchard at Vellanikkara, revealed that among various biorational approaches, the methyl eugenol bottle trap and methyl eugeonl + banana lure swab formulation on the tree trunk recorded the lowest fruit damage as compared to other treatments. The results also recorded that among the different biorational approaches evaluated, methyl eugenol bottle trap recorded the highest net profit and benefit cost ratio in the management of mango fruit flies.

19. The hot brine dip treatment for the disinfestation of the affected fruits revealed that a 15 minutes dip in 0.5 per cent brine at 50°C - 55°C effectively destroyed the oviposited eggs and the latent maggots potentially damaging the fruits during the post harvest and storage bringing an additional prevention of fruit loss by 44 per cent.

20. In the search for natural enemies of mango fruit flies a larval-pupal parasitoid viz., *Biosteres arisanus* (Sonan) was found and identified in the *B. dorsalis* at Vellanikkara with a very low natural parasitisation rate of 2.76 per cent only. The predatory red ant viz., *Oecophylla smaragdina* was also observed to be feeding on the dead and entrapped flies in the traps without any direct confirmation of their predation on the live stages of mango fruit fly.

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SPECIES DIVERSITY OF THE ORCHARD FRUIT FLY COMPLEX AND THE BIORATIONAL MANAGEMENT OF THE MANGO FRUIT FLY, *Bactrocera dorsalis* (Hendel) (Diptera: Tephritidae)

By

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ABSTRACT OF THE THESIS

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ABSTRACT

The mango fruit fly, *Bactrocera dorsalis* (Hendel), is one of the serious pest of orchard systems, causing severe economic damage in fruit crops. Because of the enigmatic behavioural adaptations of the fruit fly species in different host fruits, the conventional pest management practices often provide unsatisfactory results. More over, the use of chemical interventions result in the usual set backs of insecticide resistance, pest resurgence, destruction of natural enemies and pollinators, pesticide residue in the harvested produce and related environmental and health hazards. Hence, there is an impetus for research and development on sustainable and eco friendly fruit fly management technology in orchard crop systems.

In this context, the study on "Species diversity of the orchard fruit fly complex, and the biorational management of the mango fruit fly, *Bactrocera dorsalis* (Hendel) (Diptera : Tephritidae)" was carried out in the Department of Agricultural Entomology, College of Horticulture at Vellanikkara and farmers field during 2005-07. Investigations were undertaken to study the population dynamics of orchard fruit fly complex in different host fruits and to correlate its seasonal occurrence with the weather parameters, to evaluate the different types of lure material for fruit fly monitoring and management by various lure application techniques, to evaluate the emergence pattern, location of alightment on host trees, optimum height of trapping and distribution of fruit fly, to evaluate different food lures under cage experimentation and finally, to evolve an eco-friendly and biorational pest management strategy against *B. dorsalis* in mango orchards.

The population of orchard fruit flies responding to methyl eugenol was monitored at weekly intervals from August 2005 to July 2006 at three locations in the KAU orchards in Vellanikkara and Mannuthy campuses and found that the highest peak of population was observed during the second week of March and the lowest during the third week of December. As different orchard fruits are serving as hosts for the *B. dorsalis* complex such as sapota, lovi lovi, citrus, fig, guava, carambola and jack, their population attained several peaks as and when different fruits were available in plenty in their respective fruiting seasons.

Correlations between fruit fly catch (in mango) in ME traps and the weather parameters at Vellanikkara revealed that the maximum and minimum temperatures showed a significant positive correlation with the fruit fly population. Among other host fruits, rainfall showed a positive correlation with the fruit fly population in sapota. In Lovi lovi, maximum and minimum temperatures as well as relative humidity showed a positive correlation with the fruit fly population. In jack maximum and minimum temperatures increased the catch of fruit fly numbers. In guava, fig and carambola, all the weather parameters showed a non significant correlation with fly population.

The population of mango fruit flies and other species responding to methyl eugenol traps were monitored at monthly intervals from August 2005 to July 2006 at Vellanikkara. Four species of fruit flies viz., *B. dorsalis, B. caryeae, B. correcta* and *B. zonata* were identified and the average monthly catches were 1436.41, 77.83, 27.25, 19.33 flies/trap respectively. The species diversity index worked out revealed that the mango fruit fly, *B. dorsalis* is the most dominant species as compared to the other three species.

Sex ratio studies revealed that *B. dorsalis* population in ripe mango, bread fruit, rose apple and fig was more rather male biased with 1:0.99, 1:0.89, 1:0.97, 1:0.94 respectively, while, there was a slight female dominance (1:1.06) in guava.

The optimum height for the ME bottle traps for fruit fly monitoring and management in mango was determined to be at two metre above the ground level during both rainy and non rainy periods in mango.

The optimum height for the lure swab treatment on mango and bread fruit trees was found to be again at two metre height with more number of entrapped flies while, in sapota, it was only at 1.5 metre height. Among the four directions of attractional and behavioural orientations to the lure swabs, the western and southern sides of the tree trunks were having the higher number of fly catches as got stuck.

The emergence rate of mango fruit flies from the soil was recorded to be higher from the middle zone at a distance of 2-3 meters radial distance from the tree base. The peak time of adult fly emergence from the soil litter was found to be between 6 am to 10 am.

The time of attraction in the *Spathiphyllum* plants acting as a trap plant for fruit fly attraction to its spadix was found to be between 7 to 8 am.

The studies on the behavioral alightment and hiding place of the adult flies on the mango tree revealed that they prefer to colonize on the under side of the leaves in the lower canopy during the season. The flies were also observed to frequent more on the proximal end of the maturing fruits especially borne in the lower branches of the tree canopy.

The fruit fly attraction to different food lures when tested under cage experimentation proved that the flies were attracted more towards the fruit macerates of banana varieties viz., Poovan and Robusta and also to other host fruits namely Prior variety of mango followed by rose apple.

The maximum response of fruit flies to ME traps as evidenced by the male catch was determined between 4-6 pm and 6-8 am under shaded tree canopy during the mango season.

The studies on the population levels of mango fruit fly in ten different locations from Thrissur (Kerala) to Sadayanpallam (Tamil Nadu) over a distance of 75 km with the ME traps revealed that the trend of population increase from flowering to harvest across the region was almost similar and there was no probability of any suspected migration.

Among mango varieties observed, the Prior and Alphonso were found to be having the maximum fruit fly infestation. Neelam, Moovandan and Chandrakaran were the least susceptible ones. Among the other host fruits, rose apple and guava had recorded higher infestations as high as 100 per cent and 30 per cent respectively.

The results on the sticky trap experiments in mango and sapota orchard revealed that a vertically hanging yellow poly pack board of size 30 x 20 cm was having the maximum number of entrapped fruit flies.

The newer application technique with sticky lure swabs on the tree trunks with gelatin based formulations in combination with ME and ME- banana macerate proved efficient in both trapping the adult flies and consequent reduction in fruit damage.

Three field experiments undertaken to evaluate the efficacy of selected biorational techniques against mango fruit fly in variety Prior and Alphonso in the College orchard at Vellanikkara, revealed that the methyl eugenol bottle trap and methyl eugeonl + banana lure swab formulation on the tree trunk recorded the lowest fruit damage as compared to other treatments.

Post harvest loss by the latent damage incited by the already oviposited eggs on the pre ripened fruit before harvest could be successfully prevented by the hot brine (0.5%) dip treatment of the fruits at 55°C for 15 minutes which afforded 100 per cent protection by the fly maggots during post harvest storage.

Studies on the natural enemies of *B. dorsalis* complex in mango, resulted in the identification of one larval pupal parasitoid namely *Biosteres arisanus* (Sonan), which was having only 2.76 per cent natural parasitism on the maggots with in the fruits as evidenced by the ecloded adult parasitoid under the laboratory conditions.