

**SEASONAL INCIDENCE, BIOLOGY AND MANAGEMENT
OF PEACH FRUIT FLY UNDER LOW HILLS CONDITIONS
OF HIMACHAL PRADESH**

Thesis

**Submitted by
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(NH-2021-01-M)**



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In partial fulfilment of the requirements for the degree of

**MASTER OF SCIENCE
(AGRICULTURE)
ENTOMOLOGY
DEPARTMENT OF ENTOMOLOGY**

**COLLEGE OF HORTICULTURE AND FORESTRY
NERI, HAMIRPUR (HP) – 177 001 INDIA**

2023

Acknowledgements

With all humility and sincerity, I bow before the 'ALMIGHTY' whose grace and blessings gave me courage and wisdom to accomplish this important task of my life.

I would like to express my special gratitude to College of Horticulture and Forestry, Neri, for providing opportunity for completing my Master's programme.

The name on the cover would never have been there without the constant help, advice and guidance provided by my advisor **Dr. V.K Rana**, Professor and Head, Department of Entomology. I express deep sense of gratitude and regards for his inspiring guidance, constant encouragement, valuable suggestions, logical and necessary criticism, innovative ideas.

It is my utmost pleasure to avail this opportunity to extend my heartiest gratitude to the worthy members of my advisory committee, I sincerely thank **Dr. Sanjeev Kumar Banyal** (Associate Professor, Department of fruit science) and **Dr. Monica Sharma** (Associate professor, Department of plant pathology) for their guidance, encouragement and valuable suggestions during the course programme, investigations till completion of thesis.

I acknowledge my heartfelt thanks to the respected faculty member of Department of Entomology **Dr. Vijay Chandel** and **Dr. Monika Kalia** for their needful help and wonderful suggestions during entire course of studies.

I express my sincerely thanks to Professors, Librarian, Dean for providing me the essential facilities to conduct the proposed investigation. I cordially extend my special thanks to Entomological workers of COH&F, Neri for their conscious support and cooperation.

'Thanks' is too small a word to express my deep sense of gratitude and affection to the people who mean the world to me, my mother (Mrs. Shanta Kalotra), father (Mr. Ajay Kalotra), brother (Rahul Kalotra) and my grandparents whose love, affection and motivating words have always inspired me to reach the sky.

Words are not enough to express my emotions to all my friends and batchmates especially Simran, Rishabh, Riya, Shivani, Sonali, Varun, Shailja, Hazara aunty and Vikrant sir and seniors Dinesh, Rajat and Vasundhra for their needful help, moral support, and co-operation during my research work.

I am thankful to all those who have helped me directly or indirectly and whose names I forgot to mention in this endeavour.

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LIST OF ABBREVIATIONS

%	:	Per cent
/	:	Or
@	:	At the rate of
~	:	Near about
°E	:	Degree East
°N	:	Degree North
a.i.	:	Active Ingredient
ANOVA	:	Analysis of variance
BAT	:	Bait Annihilation Technique
CD	:	Critical Difference
cm	:	Centimeter
Conc.	:	Concentration
cvs.	:	Cultivars
df	:	Degree of freedom
<i>e.g.</i>	:	<i>Exempli gratia</i> (for example)
EC	:	Emulsifiable Concentrate
ed.	:	Editors.
<i>et al.</i>	:	<i>et alia</i> (and others)
<i>etc.</i>	:	<i>et cetera</i> (and other similar things)
g	:	Gram
Ha	:	Hectare
<i>i.e.</i>	:	<i>id est</i> (that is to say)
IPM	:	Integrated Pest Management
kg	:	Kilogram
L	:	Litre
LD ₅₀	:	Lethal Dose 50
m	:	Meter
MAT	:	Male Annihilation Technique
MC	:	Methyl eugenol + Cue lure
ml	:	Milliliter
mm	:	Millimeter
NSKE	:	Neem Seed Kernel Extract
°C	:	Degree Celsius
OD	:	Oil Dispersion
RBD	:	Randomized Block Design
SC	:	Suspension Concentrate
SE	:	Standard Error
spp.	:	Species
t	:	Tonne
<i>Viz.</i>	:	<i>Videlicet</i> (namely)
w.e.f.	:	With effect from
WSC	:	Water Soluble Concentrate

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CERTIFICATE- I

This is to certify that the thesis entitled, “**Seasonal incidence, biology and management of peach fruit fly under low hills conditions of Himachal Pradesh**” submitted in partial fulfillment of the requirements for the award of the degree of **MASTER OF SCIENCE (AGRICULTURE) ENTOMOLOGY** in the discipline of **PLANT PROTECTION** of Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni Solan (H.P.) - 173230 is a record of bonafide research work carried out by **Ms. ANUPAMA KALOTRA (NH-2021-01-M)** daughter of Sh. Ajay Kalotra under my supervision and that no part of this thesis has been submitted for any other degree or diploma.

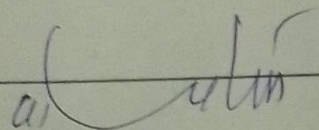
This assistance and help received during the course of investigation has been fully acknowledged.

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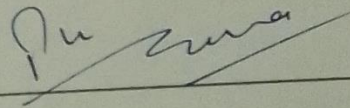
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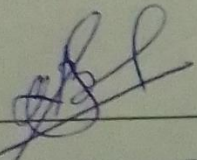


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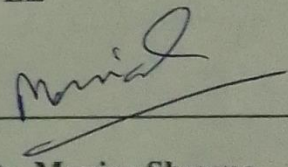


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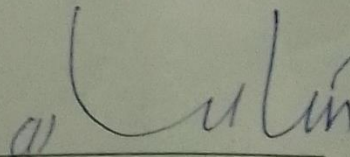
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Introduction

Chapter -1

INTRODUCTION

The peach (*Prunus persica*) is a valuable fresh and canned fruit crop of Himachal Pradesh. Additionally, it contains significant amounts of phytochemicals such as carotenoids, flavonoids and anthocyanins. Peaches are also a very rich source of potassium, iron, fibre, vitamin A and vitamin C (Hancock and Scorza, 2008).

The area under its cultivation in India is 18 thousand hectares with a yearly production of 1,08,000 MT (Anonymous, 2021). In Himachal Pradesh, the area under its cultivation is 4930 hectares with a production of 7,110 MT (Anonymous, 2021). In India, peaches are cultivated commercially in the mid-hills of Himachal Pradesh, Jammu and Kashmir, the hilly regions of Uttarakhand and the subtropical plains of the north (Uttar Pradesh, Punjab, and Haryana), with some production also taking place in the hilly regions of eastern states. Due to its ease of adaptation to various ecological circumstances and early fruit set, the peach (*Prunus persica* L. Batsch) is an important and widely grown stone fruit crop in temperate parts of the world. Peach require a chilling period of 200–1000 hours below 45°F for breaking bud dormancy and they happen to be moderately resilient to winter conditions (Rana and Sharma, 2012). Peaches are a fruit native to temperate zones, although low chilling varieties have been created that are suited for sub-tropical regions (Kunden et al. 2004). The majority of peach cultivars are regionally adapted, performing well in one area and poorly in another, while some of the qualitative characteristics are subject to change depending on the current environmental circumstances (Verma et al. 2009). After apples and pears, peaches are the third most produced temperate fruit species.

True-winged fruit flies are members of the tephritidae family, one of the largest groups in the order Diptera. It is found in temperate, subtropical, and tropical regions of the world and has about 500 genera and over 4000 species (Rattanapun, 2009; Khalil et al. 2010; Mosleh et al. 2011).

Fruit flies are among the most destructive agricultural pests in the world, posing serious risks to horticulture crops, including both fruits and vegetables (Clarke et al. 2011 and Hendrichs et al. 2015). According to numerous variables including region, season, variety and

their population, tephritid fruit flies reduce fruit and vegetable yields by 90 to 100% (Sapkota et al. 2010). In India, fruit flies of the genus *Bactrocera* (Diptera: Tephritidae), which can cause losses of up to 100% if not controlled in time, attack the majority of crops of fruits and vegetables. Along with wild fruit and vegetable crops, they affect nearly all cultivated fruit crops as well (Ndiaye et al. 2008 and Ekesi et al. 2016). In Pakistan, the oriental fruit fly causes a serious hazard to fruit, attacking variety of fruits like guava, persimmon, peach and apple (Hussain ali et al. 2010).

One of the most dangerous insect pests is the peach fruit fly, *Bactrocera zonata* (Saunders) (Diptera: Tephritidae), which attacks over 50 fruit species, including the guava, mango, peach, apricot and citrus species (White and Elson-Harris, 1994). The peach fruit fly, *Bactrocera zonata* (Saunders) is introduced into other parts of the world from South and Southeast Asia (Draz, 2016). When female fly choose suitable hosts, they lay their eggs beneath the skin of those hosts. When the larvae hatch, they feed on the flesh, damaging a substantial amount of the fruit and fruit becomes unfit for consumption or sale (Christenson and Foote, 1960).

More than 200 different species of fruit flies have been identified in the Indian subcontinent. However, just a few species roughly ten are regarded as significant pests of fruits and vegetables. The majority of these species are polyphagous, have high rates of reproduction and can spread very quickly across a large region, making them a serious as well as challenging threat to those who grows fruits and vegetables (Saeed et al. 2022). According to Rai et al. (2008) and Choudhary et al. (2018), *B. zonata* is a significant and polyphagous insect pest of fruit crops that is present around the world and is particularly prevalent in certain regions of India.

One of the main constraints on peach production is the fruit fly attack. Both the amount and quality of peach fruits are affected.

Basic information on the occurrence of the pest is required in order to build an insect pest management programme towards a particular agroecosystem. This information aids in determining the best time to take action and the most effective approach for control.

A variety of techniques, such as cultural, biological, chemical, mass trapping and baits, MAT's (male annihilation technique) and SIT (sterile insect technique), quarantine and post-harvest approaches are included in the integrated management approach against fruit flies of

fruit plants (Mohamed Kabbashi ,2014). The use of chemical insecticides as a standard control method has a number of drawbacks, including insect resistance and persistent problems (El-Gendy 2018). For the control of fruit flies, three techniques—male annihilation method (MAT), bait application technique (BAT), and sterile insect technique (SIT)—have previously received global validation (Stonehouse et al. 2002; Singh and Sharma, 2011; Rull et al. 2012 and Patel et al. 2023). The pest's adults are present throughout the year, but it is challenging to monitor and manage the pest's juvenile stages in the field because the maggots stay inside the fruit and the pest pupates and overwinter in the soil (Sharma et al. 2015). The most common way of controlling fruit flies is the attract and kill method, which involves employing male attractants along with toxicants to kill male fruit flies (Vargas et al. 2010). Methyl eugenol, in addition to being a sex attractant, can be utilised in male annihilation techniques for eradication or control programmes against *Bactrocera zonata* (Afia, 2007). Fruit flies can be controlled with pesticides using a variety of application techniques, including cover spray and bait stations.

Monitoring plays a crucial role in documenting fluctuations in the population levels of fruit flies and implementing necessary control measures. The growth of the pest population is primarily influenced by various weather parameters. Understanding these weather parameters is advantageous in examining the increase of the pest population, thereby assisting in forecasting, and taking timely measures.

Considering the above perspectives, the current research entitled “Seasonal incidence, biology and management of peach fruit fly under low hills conditions of Himachal Pradesh” is conducted with following objectives.

1. To observe the seasonal incidence of peach fruit fly.
2. To study biology of peach fruit fly (*Bactrocera zonata*).
3. Evaluation of different management techniques against the pest.



Review of literature

Chapter - 2

Review of literature

According to Ekesi and Mohamed (2011), tephritid fruit flies are the biggest hazard to horticulture. The two species, *Bactrocera dorsalis* and *Bactrocera zonata*, have a predominant link to the peach fruit crop. This chapter discusses previous work done, with a focus on the goals chosen for the current investigation that is seasonal incidence, biology, evaluation of different protein baits, male annihilation techniques and its management with insecticides and non- insecticide methods.

2.1 Seasonal abundance

According to Gupta et al. (1990) the population of *Bactrocera zonata* male species occurred from the second week of April to the second week of November. On peach fruit, adult activity peaked around the second week of July; however, the greatest catch took place during the third week of June.

Agarwal et al. (1999) conducted a study in Bihar where they reported the average number of *Bactrocera dorsalis* and *Bactrocera zonata* trapped in mango orchards during April and August. The findings indicated that in April, the average number of *B. dorsalis* trapped per fruit fly trap per week was 39.94, while in August, it increased to 134.92 fruit flies per trap per week for *B. zonata*.

According to Jalaluddin et al. (1999), in the state of Tamil Nadu, three distinct peaks of *Bactrocera zonata*, *Bactrocera correcta*, and *Bactrocera dorsalis* were observed in guava orchards. The first peak was observed during the second fortnight of June, followed by the second peak occurring during the second fortnight of July. Lastly, the third peak was observed during the second fortnight of August.

During the first two weeks of July, Anjum et al. (2000) saw the largest *B. zonata* fruit fly population. Compared to *B. dorsalis*, *B. zonata* had a greater population. They observed a substantial positive correlation between the *Bactrocera* species caught in traps and the maximum and minimum temperatures.

Rajitha and Viraktamath (2006) observed the population of *Bactrocera* fruit flies using

methyl eugenol traps in a guava orchard in Dharwad, Karnataka. On the basis of total number of fruit flies, the maximum population were observed on 30th (157.64 flies), 43rd (218.75 flies) and 45th (379.82 flies) standard week.

Saafan et al. (2006) discovered that during the two successive seasons (2003 and 2004), the capture per trap per day of PFF had means of 34.21 and 19.87 flies (in peach), 50.90 and 20.45 flies (in guava orchards), and 8.28 and 8.44 flies (in fig orchards). During the 2003, PFF populations peaked in June (on peach), August (on guava), and November (on fig orchards), whereas the minimum population was observed in peach and guava orchard during May month and in fig orchards during January.

Deepa et al. (2009) monitored the abundance of *Bactrocera dorsalis*, *Bactrocera correcta* and *Bactrocera zonata* throughout the season. In horticulture orchard, the maximum population of *B. zonata* was monitored on second week of October 2006 and March 2007. The maximum population of *B. correcta* was observed on second week of December 2006 and second week of April 2007 while the highest population of *B. dorsalis* was recorded during fourth week of April.

Choudhary et al. (2012) monitored the fruit flies during fruiting period of mango in 2012 by using methyl eugenol traps. They observed three fruit fly species, *Bactrocera dorsalis* (Hendel) *Bactrocera zonata* (Saunders), and *Bactrocera diversa* (Coquillett) during the monitoring period. The result concluded that *B. zonata* was the most predominant species among other species infesting mango fruits in the state.

Ghanim (2013) conducted a study comparing the effectiveness of five different concentrations of methyl eugenol (10%, 25%, 50%, 75%, and 100%) in combination with three insecticides from distinct pesticide groups: fenrithion, spinosad, and a mixture of thiamethoxam and abamectin. The findings of the study indicated that there were no notable distinctions in the performance of concentrations 50%, 75%, and 100% of methyl eugenol when used in conjunction with spinosad. Moreover, these concentrations showed a significantly higher impact on capturing male fruit flies compared to the use of 10% and 25% concentrations. In conclusion, the dilution of methyl eugenol in paraffin oil down to 50% when combined with spinosad as an insecticide did not exhibit a significant adverse effect on the captured male fruit flies. Instead, it demonstrated strong efficacy in controlling the *B. zonata* population.

Kakar et al. (2014) observed the level of fruit flies' infestation in guava and peach fruit. The investigations showed that fruit fly infestations gradually increased from mid-April and peaked in mid-August and mid-September, while they decreased in guava plantations from the end of September to mid-November. Fruit fly infestation in peach orchards was highest in August.

According to Sarwar et al. (2014), the peach fruit fly species, *B. zonata*, was commonly found in the traps and collected fruits, making it the most prevalent species. The surveillance of fruit fly populations in mango orchards indicated that the peak population of *B. zonata*, with an average of 40-30 flies per trap per week, and fruit infestation rates ranging from 9.05% to 7.45%, were observed during the months of June, July, and August.

Pal et al. (2015) reported nine fruit fly species viz., *Bactrocera zonata* and *Bactrocera affinis* was active throughout the season where, *B. diversa*, *B. correcta* and *B. dorsalis* was active during kharif and rabi season, were trapped using methyl eugenol traps. The activity of *B. nigrofemoralis* and *B. coudata* was observed during the kharif and rabi seasons, while *B. yercaudiae* was active during kharif and zaid seasons but *B. cucurbitae* was active throughout the season, were trapped using cue lure (CL) baited traps. In the kharif season the peak population of fruit fly species were observed.

In two districts of Uttar Pradesh Kumar et al. (2018) observed the population of different fruit fly species during 2013. They identified four species of fruit flies, including *B. zonata*, *B. dorsalis*, *B. correcta*, and *B. diversa* on mango orchards. The peak population of *B. zonata* was observed in the month of July whereas lowest population observed in January month. The peak population of *B. dorsalis* was observed in August where lowest population occurred in January. *B. correcta* and *B. diversa* species population were low throughout the season.

Begam et al. (2021) conducted a study on the population dynamics of two Tephritid fruit fly species, namely *Bactrocera dorsalis* and *Bactrocera correcta* Bezzi, in Tamil Nadu from January to December 2018. They monitored the fluctuation in fruit fly populations by capturing flies in methyl eugenol traps placed at fixed locations at fortnightly intervals. The population of *Bactrocera dorsalis* exhibited a gradual increase, starting from the first fortnight of April with 6.5 flies captured per trap per fortnight. It reached its first peak during the first fortnight of July, with a significantly higher count of 113.5 flies per trap per fortnight. As for

Bactrocera correcta, the first peak occurred during the second fortnight of May, with 15.5 flies captured per trap per fortnight. The population of *B. correcta* started to decline, reaching its lowest count during the second fortnight of December, with only 2.0 flies captured per trap per fortnight.

In their study, Khan et al. (2021) aimed to investigate the population dynamics of fruit fly species *B. zonata* and *B. dorsalis* in guava and mango orchards, using methyl eugenol-baited traps. The findings revealed significant fluctuations in the population of both species throughout the year. *B. zonata* was found to be the dominant species in both mango and guava orchards compared to *B. dorsalis*. The highest average number of *B. zonata* flies per trap (3690.57 flies/trap) was captured in August 2018 in the guava orchard. In the mango orchard, the peak population of *B. zonata* (4062.8 flies/trap) was recorded in May 2019. As for *B. dorsalis*, its abundance in the guava orchard reached its highest level (394.625 flies/trap) in August 2018. However, in the mango orchard, there was an upward trend in the population starting from April, with the highest catches of 521.4 flies/trap observed in June.

2.1.1 Influence of weather parameters on fruit fly population

Fruit fly population dynamics were studied in Andhra Pradesh by Sarada et al. (2001). According to their conclusions, fruit flies were most prevalent during the months of May and June, when the fruit was at its maturity stage. Fruit fly populations were positively correlated with mean temperature, mean rainfall, and relative humidity, but negatively correlated with mean relative humidity.

According to Singh and Mann (2003), the population of *Bactrocera dorsalis* was peaked in September month, dropped in July, and peaked again in February in Punjab peach orchards. Climate variables including rainfall and temperature were positively correlated with population growth.

In the study conducted by Raghuvanshi et al. (2012), fruit flies were consistently abundant in Cue-lure baited traps throughout the entire year. The researchers observed two peaks in fruit fly activity, one during summer and the other during the kharif (Autumn) season. In the kharif season, the most significant bitter melon fruit damage (62.70%) was recorded during the 45th SW, while a second peak of 49.70% fruit damage occurred in the 15th SW period. The study revealed that temperature, both maximum and minimum, exhibited a notable

and positive correlation with adult fruit fly abundance, fruit damage, and pupal population.

Stanley et al. (2015) used methyl eugenol traps in several crop fields in the Himalayan Hills to study the seasonal incidence of three different fruit flies, *B. dorsalis*, *B. zonata*, and *B. diversa* which is correlated with temperature, rainfall, and relative humidity. The highest population of fruit fly was observed from May to October. However, no population was observed in the month of January. The species that appeared from March to August was *B. zonata*, which was the most prevalent. Fruit flies were positively correlated with mean temperature.

According to Draz et al. (2016) *Bactrocera zonata* was found in fruit orchards in several agro-ecosystems in Egypt. Additionally, they investigated the effectiveness of McPhail traps and Jackson traps for male capture from May 2014 to April 2015. In terms of McPhail traps, the fall season had the highest number of trap catches, although the other three seasons saw similar types of mass traps. In McPhail traps, the correlation between trap catches and wind direction was negative, whereas the correlation between trap catches and mean temperature was positive.

Bana et al. (2017) placed traps containing methyl eugenol on plywood bases within mango orchards located in Navsari, Gujarat. They observed that these traps captured a significant number of *B. dorsalis* fruit flies during the fruiting and ripening period in June and July. Additionally, their study highlighted the significance of specific weather conditions, including minimum temperature, evening relative humidity, rainfall, and wind velocity, as influential factors in predicting fruit fly captures.

Khan and Naveed (2017) used methyl eugenol traps to track the population of *B. zonata*. Fruit fly occurrence and population fluctuations were compared with weather variables such as temperature, sunshine, and relative humidity. The peak population of fruit fly was observed in the month of August and afterwards it started to decline. The minimum population was observed in the month of November, December, January, and February, respectively. The population of fruit flies correlated positively with temperature and marginally negatively with relative humidity.

In the study conducted by Wazir et al. (2019), Green victory Methyl Eugenol (ME) fruit fly traps were utilized to assess the seasonal occurrence of fruit flies during the period of 2017-2018. The researchers also investigated the impact of various weather parameters on the

population dynamics of the fruit fly. The findings revealed that the fruit fly infestation was observed to be highest during the 26th Standard week with (317 fruit flies captured per trap). Furthermore, the correlation analyses demonstrated that weather parameters played a significant role in influencing the population growth of the fruit fly, as well as its trap captures on summer squash. Specifically, the fruit fly population exhibited a strong positive correlation with mean relative morning humidity, relative evening humidity, and rainfall. However, it showed negative correlation with maximum temperature.

2.2 Biology

In a study conducted by Bhatia and Mahto (1969), the life cycle of *Bactrocera spp.* was investigated, and their findings revealed that the duration of the life cycle varied depending on the temperature conditions. At 15 °C, the life cycle was observed to be 36.3 days, while at 20 °C, it took approximately 23.6 days to complete. The duration further decreased to 11.2 days at 27.5 °C, and at 30 °C, the life cycle was completed in about 12.5 days.

Fletcher (1987), observed the basic life cycle of all true fruit flies, which are members of the family Tephritidae of the order Diptera, involves the female depositing eggs into ripening fruits, which hatch, and the maggot move into the soil after experiencing three larval instars, where pupation occurs.

In a study conducted by Shehata et al. (2008) to investigate the biological aspects of *Bactrocera zonata* (oriental fruit fly), five different fruits were tested, namely guava, pear, peach, apple, and apricot. The experiment revealed that pear was the most favored fruit, showing the highest pupal production with a total of 1651 pupae. Following pear, guava had the second-highest pupal production with 1640 pupae, while peach had 1626 pupae. Apricot and apple had relatively lower pupal production, with 1259 pupae and 1223 pupae, respectively.

Khattak et al. (2012) conducted a bionomics study on *Bactrocera zonata* and reported various findings related to its life cycle. According to their research, the eggs of *Bactrocera zonata* took approximately 2 days to hatch. However, the hatching percentage observed under laboratory conditions was 23%. The larval stage of *Bactrocera zonata* lasted for a period ranging from 7 to 9 days, while the pupal stage ranged from 11 to 12 days. Adult flies' lifespan was observed to be around 180 days. Furthermore, the researchers noted that each female fly

had an average fecundity of 65 eggs. In summary, Khattak et al. (2012) found that *Bactrocera zonata* had a relatively short incubation period for its eggs, but the hatching percentage was low, potentially due to the absence of casein in the diet. The larval and pupal stages had specific duration ranges, and the adult flies exhibited a lifespan of approximately 180 days. The average fecundity per female was recorded as 65 eggs.

Rauf et al. (2013) conducted a laboratory experiment to investigate the ovipositional preference of *Bactrocera zonata* (oriental fruit fly) on various fruits, including apple, guava, citrus, banana, ber, and chikoo both free choice and no choice conditions were examined. The results led to the conclusion that guava was the most preferred host, with an average pupal recovery of 318.00 ± 4.61 pupae per fruit in the free choice scenario and 434 ± 2.64 pupae per fruit in the no choice scenario. Following guava, banana was the next preferred host with an average of 266.00 ± 4.5 pupae per fruit in the free choice experiment, while ber showed preference in the no choice experiment with an average of 177.00 ± 2.08 pupae per fruit. On the other hand, apple and citrus were found to be the least preferred hosts.

Mir et al. (2014) conducted a study on *Bactrocera cucurbitae* and reported various developmental and reproductive characteristics. The results showed that the egg incubation period lasted for an average of 16.8 ± 4.9 hours. The larval stage lasted around 4.5 ± 1.2 days, followed by a prepupal period of approximately 0.8 ± 0.25 days. The pupal stage lasted for about 8.4 ± 0.51 days. The pre-oviposition period, ranged from 10 to 15 days, while the oviposition period, ranged from 12 to 28 days. The number of eggs produced by *Bactrocera cucurbitae* varied between 58 and 92. The sex ratio of the flies was observed to be 1.0 ± 0.14 .

According to Kalia and Yadav (2015), their study demonstrated that all five fruits examined, namely mango, papaya, guava, sapota, and banana, supported the complete development of fruit flies throughout the year when maintained at a constant temperature of $27 \pm 1^\circ\text{C}$ and 65% humidity. The incubation period varied between fruits, with mango having the shortest duration of 1.7 days and sapota having the longest duration of 3.5 days. The larval period was found to be maximum in guava, lasting 9.7 days, while banana had the shortest larval period of 6.0 days. Sapota exhibited the minimum pupal period of 8.5 days. The life cycle of the fruit flies took the least amount of time in mango, completing in 18 days, while guava had the longest duration of 21.6 days.

Naik et al. (2017) studied the biology of *Bactrocera dorsalis* (oriental fruit fly) on

custard apple. According to the results, the average length and breadth of immature stages that is egg, maggots and pupae were 1.36 ± 0.12 mm and 0.25 ± 0.13 mm, 8.18 ± 0.84 and 2.25 ± 0.70 mm, 4.08 ± 0.58 mm and 1.82 ± 0.69 mm, respectively. The length of adult male and female was 6.20 ± 0.73 and 8.13 ± 0.69 mm, respectively.

In the research conducted by Vasudha et al. (2019) focusing on the life history traits and immature stages of *B. tau*, several key findings were reported. The incubation period was observed to be approximately 1.21 ± 0.06 days, while the total larval duration lasted about 6.60 ± 0.15 days. Additionally, a pupal period of around 7.45 ± 0.23 days was noted. The researchers further observed that the entire life cycle of *B. tau* was completed in approximately 15.26 ± 0.23 days.

2.2.1 Egg

According to Narayanan and Batra (1960), the eggs were deposited individually or in clusters ranging from 2 to 15, positioned just beneath the surface of the fruit skin at a depth of 1-4 mm. The incubation period of the eggs varied depending on the season. In March-April, it ranged from 2-3 days, while in summer, it was shorter at 1-2.25 days. However, during winter, the incubation period could extend up to 10 days.

Mann (1990), observed that *Bactrocera dorsalis* (oriental fruit fly) deposits its eggs within the host tissue, and the hatching process occurs within a period of 1 to 3 days.

Manzar and Srivastava (2009) provided information regarding the average incubation period, temperature, and relative humidity. In 2002, they observed that the mean incubation period was approximately 1.7 ± 0.12 days. The temperature ranged from 31.9 to 32.2 °C, and the relative humidity varied between 56.7% and 62.8%. In contrast, in 2003, they found that the mean incubation period was slightly shorter, averaging at 1.4 ± 0.16 days. The temperature range recorded during that year was 27.3 to 30.8 °C, and the relative humidity ranged from 60.6% to 81.2%.

According to the findings of Waseem et al. (2012), they observed certain characteristics of freshly laid eggs. These eggs were described as cylindrical in shape, elongated and slightly curved. They had a shiny white colour and tapered towards both ends, with the posterior end being rounded and the anterior end more pointed. The average length of egg was 1.03 ± 0.16 mm and an average breadth of 0.23 ± 0.04 mm.

In West Bengal, Laskar (2013) studied the biology of *B. cucurbitae* on bitter gourd and pumpkin fruits under controlled laboratory conditions. The study found that on bitter gourd, the average length, breadth, and incubation period of the eggs were approximately 1.28 ± 0.05 mm, 0.26 ± 0.05 mm, and 1.85 ± 0.22 days, respectively. On pumpkin, the corresponding measurements were about 1.26 ± 0.06 mm, 0.25 ± 0.05 mm, and 1.90 ± 0.29 days.

Ashoka and Javeregowda (2019), discovered that the incubation period of *B. dorsalis* eggs on mango fruit exhibited significant variations under laboratory conditions. Among the mango varieties tested, Dasherri had the longest incubation period, averaging at 3.5 days, followed by Neelum at 3.0 days and Rajgira, Pairi and Mallika at 2.5 days. In contrast, the mean incubation period was significantly shorter for Alphonso at 1.5 days, followed by Benishan fruits at 1.6 days.

2.2.2 Maggots-

According to Narayanan and Batra (1960), the developmental period of the maggots of *Bactrocera dorsalis* varied depending on the time of the year. In September, it took 6 days for the maggots to develop. However, in December-January, this period extended to 29 days. In April, the development of maggots took approximately 12 days.

Pant et al. (1989) determined that the optimal pH for the growth and development of *Bactrocera dorsalis* larvae was 5. Under this pH condition, approximately 87.5% of the larvae successfully progressed into the pupal stage. The growth index recorded for *B. dorsalis* larvae at pH 5 was 3.88.

According to the findings of Duyck et al. (2004), the duration of maggot development in *Bactrocera zonata* varied based on temperature. The development periods were recorded as 30 days at 15°C, 10 days at 20°C, 5 days at 25°C, and 4 days each at 30°C and 35°C.

In their study, Kumar and Agarwal (2004) conducted dissections on *Bactrocera spp.* maggots and made several observations. They noted that the maggots had twelve segments and a small head segment that was amphiprotic. In terms of colour, the maggots appeared creamy-whitish.

Shivayya et al. (2007), made several observations regarding the characteristics of freshly emerged first instar maggots. These maggots were white in colour, with black mouth hooks. The length of the first instar maggots was measured to be 2.18 mm, while their width

was recorded as 0.35 mm.

According to Manzar and Srivastava (2009), the cuticle of third instar maggots was filmy and it had a coloration that ranged from yellowish to opaque. The third instar maggots also displayed a peculiar jumping behaviour.

Waseem et al. (2012) made observations on the characteristics of freshly formed second instar maggots. These maggots were elongate and ellipsoidal, with a creamy white coloration. The length of the second instar maggots was 5.18 ± 0.67 mm, while the breadth was recorded as 0.86 ± 1.00 mm.

Murtaza et al. (2021), measured the dimensions of *B. zonata* maggots and reported their length to be approximately 6.87 ± 0.04 , while the width was recorded as 1.12 ± 0.05 .

2.2.3 Pupa and pupal period-

According to Janjua (1948), during winter, *Bactrocera dorsalis* entered a hibernation phase in the pupal stage. This hibernation period typically began in the first week of November and lasted until March or the beginning of April in the plains. In hilly areas, the hibernation period extended until May or June, depending on whether the season was early or late.

Chu and Chen (1985) observed that the maximum distance covered by larvae through jumping for dispersal purposes was 70 cm. Upon entering the soil, the larvae were observed to move horizontally for up to 10 cm.

According to Kumar and Aggarwal (1998), fully grown larvae, aged between 8 and 10 days, exit the host fruit and proceed to enter the soil for the pupation process.

Dale (2002) observed that the pre-pupal period of *Bactrocera zonata* on mango ranged from 16 to 23 hours.

In their study conducted at Bangalore, Jayanti and Verghese (2002) investigated the development of *Bactrocera dorsalis* on different fruits, including banana, guava, mango, and papaya. The findings revealed that among all the fruits tested, banana exhibited the highest puparial recovery per 100 grams of fruit. Specifically, the Robusta variety of banana had a puparial recovery of 77.79 puparia, while the Elakki variety had 69.17 puparia. On the other hand, papaya showed significantly lower puparial recovery with only 9.19 pupae. In terms of puparial yield, banana was identified as the most suitable host for mass-rearing of fruit flies in laboratory conditions.

Lanjar et al. (2013) evaluated the pupal period and found that it varied between 7 and 13 days, with an average duration of 9.94 ± 1.03 days.

Abu-Ragheef and Al-Jassany (2018) found that the pupation period of the studied species was 10.8 days at $30 \pm 2^\circ\text{C}$, 23.9 days at $20 \pm 2^\circ\text{C}$, and 22.3 days under field conditions.

Murtaza et al. (2021) examined the dimensions of *B. zonata* pupae and reported that the length was approximately 3.54 ± 0.03 mm, while the width measured around 1.00 ± 0.01 mm.

2.2.4 Oviposition-

According to Foote and Carey (1987), they found that the pre-oviposition time period of the wild strain of *Bactrocera dorsalis* was 19 days, while the laboratory strain exhibited a shorter pre-oviposition period of 9 days.

Khan et al. (1993), observed that the pre-oviposition period ranged from 11 to 17 days, while the post-oviposition period ranged from 13 to 27 days.

Waseem et al. (2012) also reported that the pre-oviposition period had an average duration of 15.76 ± 2.06 days, while the oviposition period varied between 11 and 44 days.

According to the observations made by Abu-Ragheef and Al-Jassany (2018), in *Bactrocera zonata* the post-oviposition period was found to be 4.2 days at $30 \pm 2^\circ\text{C}$, 9.4 days at $20 \pm 2^\circ\text{C}$ (when the larvae fed on an artificial diet), and 5.3 days under field conditions.

2.2.5 Fecundity and hatching

Under laboratory conditions, Shivayya et al. (2007) documented that the fecundity of a female ranged from 188 to 250 eggs, with an average of 222.8 eggs.

In the study conducted by Lanjar et al. (2013), it was observed that female *B. cucurbitae* deposited eggs individually or in groups of 5 to 10, with intervals of 2 to 5 days. On average, a single female laid approximately 74.14 ± 4.90 eggs throughout its entire life cycle.

According to Laskar (2013), the hatching percentage varied, depending on the host. On pumpkin, the hatching percentage ranged from 82 to 98 percent, while on bitter melon, it ranged from 80 to 97 percent.

According to Naik et al. (2017), the average daily egg-laying rate per female of *Bactrocera dorsalis* was recorded as 12.4 ± 2.54 eggs, while the average total fecundity per female throughout its life cycle was measured as 371.9 ± 60.78 eggs.

2.2.6 Sex ratio

In their study, Rana et al. (1992) made the observation that the sex ratio of *Bactrocera zonata* male and female was approximately 1:1.10.

Jayanthi and Verghese (2002) found that the male to female ratios varied when *Bactrocera dorsalis* was reared on different fruits. The ratios were 1:1.00 on papaya, 1:1.70 on mango, 1:1.10 on guava, and 1:1.09 on banana varieties (Robusta and Ekaki).

According to Khattak et al. (2012), the sex ratio of *B. zonata* male and female was 1:0.95.

Laskar (2013) examined the sex ratio in different hosts and found that in bitter gourd, it ranged from 0.95 to 1.26, with an average ratio of 1.102:0.136. On the other hand, in pumpkin, the sex ratio varied from 0.91 to 1.12, with an average ratio of 0.976:0.104.

As mentioned by Kalia (2015), the sex ratio of *Bactrocera dorsalis* on various hosts, including banana, guava, papaya, sapota, and mango, can be influenced by environmental fluctuations or food availability. Specifically, the observed male to female ratios were approximately 1:1.22 on banana, 1:1.1 on guava, 1:1.06 on papaya, and 1:1 and 1:3 on sapota and mango, respectively.

2.2.7 Longevity

According to Rana et al. (1992), the longevity of male *Bactrocera zonata* individuals reared on guava was 36 to 53 days, with an average of 44.3 days. For females, the longevity varied from 47 to 72 days, with an average of 58.2 days.

Vargas et al. (1996) examined the longevity of *Bactrocera dorsalis* male and female at different temperatures, specifically 16, 18, 24, 29, and 32°C. The results indicated that the longevity of males ranged from 23.1 to 116.8 days, while the longevity of females varied from 27.5 to 133.5 days across the temperature conditions.

According to Shivayya et al. (2007), adult flies without access to food or water typically died within a range of 1.0 to 1.5 days after emerging, with an average lifespan of 1.2 days. However, when provided only with water, their lifespan increased to approximately 3.5 days. Furthermore, when adult flies were fed sugar, their longevity significantly extended to about 21 days. The study found that the type of food had a significant impact on the lifespan of adult

flies, and the addition of carbohydrates greatly improved their longevity.

Lanjar et al. (2013) recorded the average lifespan of males as 37.86 ± 1.40 days and females as 40.84 ± 0.86 days.

In their study, Mir et al. (2015) observed that the male and female *B. zonata* exhibited lifespans of approximately 48.6 and 49.6 days, respectively, when reared on peach.

According to Naik et al. (2017), when reared on custard apple, the male and female *B. dorsalis* displayed lifespans of approximately 52.48 and 64.6 days, respectively.

2.2.8 Generation duration

According to Mahmoud (2004), in Egypt, *B. zonata* underwent a total of eight to nine generations annually.

In the study conducted by Shehata et al. (2008), it was observed that *B. zonata* completed a total of eight generations within a year. The longest generation, lasting 56 days, was recorded during the winter months, while the shortest generation occurred during the summer months.

2.3 Different approaches to pest management

2.3.1 Male Annihilation Technique (Pheromone Trap)

Afzal and Javed (2001) tested five different types of wood (date, plyboard, mango, mulberry, and shisham) in a guava orchard to capture *B. dorsalis* fruit flies, in combination with four different trap shapes (oblong, square, round, and hexagonal). The findings from the study showed that traps made from plyboard with an oblong shape were the most efficient in trapping fruit flies, with mango-based traps coming in as the next most effective option.

Khan et al. (2003) monitored the population of fruit fly species and fruit infestation using methyl eugenol and cue-lure traps. The traps containing methyl eugenol indicated the highest number of adult fruit flies in orchards situated in Sheikhupura, Pakistan. Among the fruit fly species, *B. zonata* was found to have a prevalence of 49.62% on guava trees, while *B. dorsalis* exhibited a prevalence of 46.37%.

Patel et al. (2005), observed that in the mango orchard located in Gandevi, the MAT traps equipped with plywood blocks captured the highest number of fruit flies, 710 flies. This

was in contrast to traps constructed from wood sourced from twenty-one different tree varieties. However, in Anand, the highest fruit fly capture, amounting to 2309 flies, was recorded in traps containing straw board blocks.

Shukla et al. (2005), compared the trapping efficiency of plyboard, straw board, and softer board wood for fruit flies at various locations across the country. The study results indicated that the softer board blocks yielded greater captures of *Bactrocera spp.* per unit of lure volume when compared to soaked plyboard, but the softer board's effectiveness was less enduring.

Singh et al. (2008) reported that the utilization of ply board blocks infused with ethanol solvent, methyl eugenol, and malathion has demonstrated effectiveness in controlling fruit flies in orchards.

In their research, Nakahara and Muraji (2008) made notable observations regarding the attraction of different *Bactrocera* species to specific chemical cues. They found that *Bactrocera dorsalis* was attracted to methyl eugenol, while *B. cucurbitae* and *B. tau* were drawn to cue lure. However, *B. cucumis* did not exhibit any attraction to either cue lure or methyl eugenol. Interestingly, despite their distinct preferences, all three *Bactrocera* species were traced back to a common origin.

Deepa et al. (2009) conducted a study that showcased the significant effectiveness of methyl eugenol in capturing the *Bactrocera* complex.

In Pakistan, Hussain et al. (2010) conducted a study to assess the efficacy of different control methods for fruit flies. The integrated pest management (IPM) approach employed cultural control, bait application technique (BAT), and male annihilation technique (MAT) for managing the Oriental fruit fly. The results revealed that MAT exhibited the highest level of control, followed by BAT.

Shankar et al. (2010) conducted field research in Andhra Pradesh to investigate how the number and size of holes in traps affect their effectiveness in capturing *Bactrocera spp.*, including *B. dorsalis*, *B. correcta*, and *B. zonata*, in mango orchards. The results of their study indicated that traps with four holes, each measuring 20 mm in size, captured the highest number of fruit flies, averaging 9.37 flies per trap per week. Following closely behind were traps with a single hole, which recorded an average of 9.33 flies per trap per week. The impact of hole size on trap effectiveness revealed that fruit fly adults were particularly attracted to traps with

holes measuring 8 mm in diameter (also averaging 9.33 flies per trap per week). This attraction was attributed to the rapid dispersion of methyl eugenol and the influence of various weather factors.

In Karnataka, Chandaragi et al. (2012) observed that the bottle trap exhibited a significantly higher trap catch rate of fruit flies (41.13 flies/trap/week) compared to the cylinder trap (29.84 flies/trap/week). The researchers evaluated five traps with different designs, including the bottle trap, cylinder trap, sphere trap, PCI trap, and open trap, for capturing fruit flies in mango orchards.

Sharma (2012), conducted a study to evaluate the effectiveness of mass trapping method using spinosad, as an insecticide, in combination with methyl eugenol traps for controlling the *Bactrocera* species on mango, guava, sapota, and peach. The findings revealed a significant increase in fruit fly captures, with a peak capture of 179 flies/trap in 2007 and 14.8 flies/trap in 2010.

In their study, Islam et al. (2013) assessed the efficiency of various traps in attracting melon fruit flies. The traps tested included Pheromone trap (Plastic pot), GME pheromone water trap, sticky trap, Bait trap, Funnel pheromone trap, light trap, and plastic pot (Bait trap + pheromone trap). The results showed that the most effective treatment, with an average of 6.80 fruit flies per plot, was the plastic pot (Bait trap + Pheromone trap) followed by the funnel pheromone trap. However, the sticky trap and the light trap showed no significant effect on capturing melon fruit flies.

Rizk et al. (2014) conducted a study on trap catches against *B. zonata* in mango orchards. They evaluated the efficacy of four types of traps: Bottle trap, Glass McPhail trap, Plastic McPhail trap, and Abdel-Kawi trap, all of which were baited with varying doses of methyl eugenol (ME). The findings revealed that the Abdel-Kawi trap, when charged with 0.5 ml of ME, exhibited the highest effectiveness as a trapping system. ME was found to possess a strong attractive effect; however, the majority of captured male insects were observed on the outer surface of the trap and on the branches surrounding it.

Khan et al. (2015) investigated the effectiveness of methyl eugenol, cue-lure, and protein hydrolysate as monitoring tools for assessing the infestation of peach fruit flies in peach orchards. Pheromone traps were created using 2cc of methyl eugenol, cue-lure, and protein hydrolysate, along with a mixture of sugar and 2g of poison linate. The results showed that the

solutions containing methyl eugenol and cue-lure attracted a significantly higher number of male peach fruit flies compared to females. On the other hand, the protein hydrolysate solution exhibited a strong attraction towards female flies compared to males.

In a study conducted by Wazir et al. (2019), twelve distinct lure traps were assessed, each with various combinations, to monitor the fruit fly population over two seasons—2017-2018 and 2018-2019. The findings indicated a significant variation among all twelve traps during both seasons.

Khan et al. (2020) conducted a study to monitor and manage the population of the fruit fly *Bactrocera zonata* on peach trees. The experiment included various integrated pest management (IPM) treatments, such as sanitation combined with methyl eugenol, methyl eugenol without sanitation, sanitation combined with protein hydrolysis baits, protein hydrolysis baits without sanitation, neem extract combined with methyl eugenol, and neem extract combined with protein hydrolysis baits. Based on the findings of the study, it was observed that *Bactrocera zonata* exhibited a high attraction to methyl eugenol when combined with sanitation and neem extract. The maximum population abundance of *Bactrocera zonata* was recorded towards the end of September, after which the population gradually declined until the end of October.

Mariadoss et al. (2020) conducted a study on the species diversity of fruit flies that cause damage to important mango varieties, such as Banginapalli, Dasherri, and Himayat, in Ranga Reddy district of Telangana state during the years 2018 and 2019 (spanning two seasons). The researchers employed bottle traps baited with methyl eugenol as an attractant for surveillance. The findings of the study revealed the presence of significant populations of two fruit fly species belonging to the Genus *Bactrocera*, namely, *Bactrocera dorsalis* and *Bactrocera zonata*, in all three mango varieties. Among these two species, *Bactrocera dorsalis*, was observed to dominate over other species in the Banginapalli variety, while the *Bactrocera zonata*, was found to be dominant in both Dasherri and Himayat varieties throughout the two-year period.

2.3.2 Baits

Latif et al. (2002) conducted a study in the semi-arid and water-stressed region of Dera Ismail Khan (D.I. Khan) to examine the effectiveness of bait (Protein hydrolysate and molasses) and dust formulation of carbaryl at different concentrations against fruit fly

infestations in muskmelon crops. The intermittent spray of protein hydrolysate demonstrated the lowest fruit infestation rate (12%), while the molasses spray resulted in a slightly higher infestation rate (15%).

In Pakistan, Stonehouse et al. (2002) conducted a study to assess the impact of fruit fly populations on guava, jujube, melon, and mango fields under both protected and unprotected conditions. The findings indicated an infestation rate of approximately 29% in the unprotected fields, while the fields treated with the bait application technique (BAT) exhibited a lower infestation rate of 5%.

Rajitha (2004) observed that among the different protein baits tested, such as yeast, soybean, fruit fly diet, protein, and casein, certain baits exhibited a higher preference for female fruit flies. In terms of overall fruit fly populations, soybean + sugar + banana bait proved to be the most effective, capturing an average of 4.5 fruit flies per trap per week in guava. On the other hand, in mango, casein + sugar + papaya bait attracted a greater number of female fruit flies, with an average capture of 4.33 fruit flies per trap per week.

Saafan (2005) conducted a study showing that protein hydrolysate preparations, which are food attractants, were previously utilized as bait in McPhail traps. These traps successfully captured a significant number of both male and female Peach Fruit Flies and Mediterranean Fruit Flies.

Verma and Nath (2006) described an effective method to control melon fruit flies using baits, which consisted of a mixture of insecticide and food attractants. This approach proved to be attractive to the melon flies, as they would come into contact with or feed on the bait. Consequently, the poisoned food source effectively killed the flies, making it a successful strategy for managing the melon fruit fly population.

According to Ghanim (2009), the use of olfactory stimulants in attractant traps to capture Mediterranean Fruit Fly and Peach Fruit Fly can serve as an effective method for monitoring their populations and predicting the level of infestation.

Pandey et al. (2010) discovered that among the different traps tested, the banana-based poison bait trap, which consisted of banana (1 kg), carbofuran (10 g), yeast (10 g), and citric acid (5 g), was highly effective in capturing fruit flies.

In their study, Wang et al. (2010) investigated the attractiveness of volatiles emitted by decayed and fully ripened guava fruits to the fruit fly species *B. dorsalis*. The findings revealed

that the decayed guava fruits exhibited a significantly higher level of attractiveness to both immature and mature adults of the fruit fly compared to the normally fully ripened fruit.

According to the findings of Rana and Kanwar (2014), the combination of cue lure baited traps and poison bait spray demonstrated the highest efficiency in managing melon fruit flies, with a significant reduction in fruit damage (20.92%). In comparison, the control group exhibited a fruit damage rate of 45.66%.

2.3.3 Chemical and Botanical Control

The application of deltamethrin 25 EC, cypermethrin 10 EC, and malathion 35 EC at 10-day intervals (total of 4 sprays) resulted in a significant reduction in the infestation of *B. cucurbitae* on melon, ranging from 4.8% to 7.9%. This was notably lower compared to the untreated control, which had an infestation rate of 14.1%. Among the insecticides used, malathion demonstrated the highest effectiveness (Khan et al. 2003).

Zhao et al. (2004), investigated the toxicity of various insecticides, including chlorpyrifos, isazofos, quinalphos phoxim, dichlorvos, isofenphos, abamectin, trichlorfon, cyhalothrin, carbosulfan, cypermethrin, and thiomethoxam, on *Bactrocera dorsalis* pupae. They observed that the combination of trichlorfon and phoxim exhibited the highest LC50 value, which was measured at 94.24 mg/litre. Additionally, the combination of phoxim and chlorpyrifos in a 9:1 ratio displayed the highest coefficient ratio, which was recorded at 586.15.

Nath et al. (2007) discovered that the application of NSKE (neem seed kernel extract) at a concentration of 5 percent, followed by a bait spray consisting of malathion (50 g), molasses (500 g), and water (50 l), and subsequently cypermethrin, resulted in the least fruit fly damage in bottle gourd. In contrast, the untreated plot exhibited the highest level of damage.

In their study, Mahmoud and Shoab (2008) showed that neem formulations had a significant impact on *B. zonata* eggs across all tested concentrations, demonstrating a remarkable effect when compared to the control group. However, the neem treatment did not influence the sterility percentage or the emergence of adults from treated eggs at any of the concentrations used.

Sharma and Sinha (2009) evaluated the efficacy of six insecticides, namely alphamethrin, endosulfan, cypermethrin, benzoate emamectin, spinosad, and neem baan, against *B. cucurbitae*. The results indicated that alphamethrin at a rate of 20 g a.i./ha was the

most effective, causing only 5.52 per cent damage compared to the 15.14 per cent damage observed in the control group. Additionally, emamectin benzoate at a rate of 15 g a.i./ha and neem baan at a concentration of 1 ml/l also demonstrated significant effectiveness in controlling the infestations.

Urbaneja et al. (2009) documented the effectiveness of four alternative baited insecticides against the Mediterranean fruit fly (*C. capitata*) and assessed their impact on natural enemies. All baited insecticides, particularly phosmet and spinosad, exhibited significant mortality rates in Mediterranean fruit fly populations, with lambda-cyhalothrin being the least effective and demonstrating a unique incapacitating effect on surviving adults. Spinosad emerged as the most selective bait treatment for *C. montrouzieri* and *N. californicus*, while phosmet and lambda-cyhalothrin were found to be the most selective baits for *A. colemani*.

In their study on the effectiveness of various insecticides against the melon fruit fly (*B. cucurbitae*) infesting cucumber, Waseem et al. (2009) found that the neem-based product (Nimbex) demonstrated the highest efficacy. It resulted in the lowest fruit fly infestation rate at 7.33%. Acephate, spinosad, and imidacloprid followed with fruit damage rates of 8.00%, 9.00%, and 10.33%, respectively.

In the research carried out by Thakur (2011), the effectiveness of six insecticides was assessed to manage fruit fly infestations in vegetable and fruit crops. The insecticides tested were lambda cyhalothrin (0.004%), deltamethrin (0.0028%), spinosad (0.002%), garlic (3%), neem (3%), and malathion (0.05%). The results of the study revealed that lambda cyhalothrin (0.004%) exhibited the highest level of efficiency in controlling fruit fly infestations, with spinosad (0.002%) ranking second in efficacy. Furthermore, vegetable plots and fruit trees treated with lambda cyhalothrin (0.004%) and spinosad (0.002%) also demonstrated higher yields.

In their field experiments targeting fruit flies infesting cucumber and bitter gourd, Khursheed and Raj (2012) evaluated the efficacy of seven insecticides and biopesticides. Lambda-cyhalothrin at a concentration of 0.004% was identified as the most effective treatment, followed by azadirachtin at 0.0045% and carbaryl at 0.20%. On the other hand, chlorpyrifos at 0.05% and malathion at 0.05% were found to be less effective.

Bhowmik et al. (2014), conducted an experiment to evaluate the effectiveness of several

chemical treatments, including spinosad, chlorfenapyr, acephate, and deltamethrin, in managing the melon fruit fly (*B. cucurbitae*) infestation on bottle gourd. Among the following insecticides, chlorfenapyr was superior than other insecticides followed by acephate and deltamethrin.

Sawai et al. (2014) found that the treatment with DDVP (dichlorvos) was more effective than deltamethrin in managing fruit fly infestation in ridge gourd. The DDVP treatment resulted in the lowest fruit damage at 22.82%.

Khatun et al. (2015) assessed the effectiveness of abamectin, emamectin benzoate, lufenuron, and lambda-cyhalothrin in combating *B. cucurbitae*. They applied abamectin both on its own and in combination with the other substances. The results indicated that the application of abamectin led to a significant reduction in fruit infestation, specifically by 16.81%, as compared to the control group. Furthermore, when abamectin was combined with lambda-cyhalothrin, the reduction in infestation increased to 13.40%. This study's findings suggest that utilizing a combination of abamectin and lambda-cyhalothrin could represent an effective strategy for the management of the cucurbit fruit fly.

Rana et al. (2015) conducted a study to assess the impact of cypermethrin on the melon fruit fly, *Bactrocera cucurbitae* (Coq.). Third instar larvae were subjected to various doses of cypermethrin, including 0.0016%, 0.0032%, 0.0063%, 0.0125%, and 0.025%, using the contact method. The results revealed that the lowest concentration of cypermethrin (0.000245%) resulted in only 1% mortality, whereas the highest concentration (0.0354%) caused 90% mortality among the larvae. Additionally, when a high dose of cypermethrin (0.025%) was applied to 50 larvae, only 9.66 larvae were able to pupate, and among those, only three pupae successfully emerged as adult flies.

According to Sharma et al. (2016), the lowest fruit infestation rates were recorded as 7.69% in 2011 and 9.09% in 2012 when treating with cypermethrin 25EC at a rate of 0.5 ml/l. Neem oil at a concentration of 5 ml/l had infestation rates of 12.50% and 13.58% in the respective years. In terms of fruit yield, cypermethrin treatment resulted in the highest yields of 191.48 q/ha and 183.33 q/ha in 2010 and 2011, respectively, followed by neem oil with yields of 189.01 q/ha and 181.48 q/ha in the respective years.

In their study, Shivangi and Swami (2017) reached the conclusion that applying spinosad at a rate of 200 ml/ha was a highly effective treatment for controlling fruit flies in

cucumber. This treatment resulted in significantly lower levels of fruit infestation, reduced numbers of damaged fruits leading to fewer pupae and oviposition marks, and ultimately minimized losses while achieving the highest fruit yield.

Vinutha and Kotikal (2018) detect that the population of *B. cucurbitae* flies on melon could be effectively reduced by using spinosad 45 SC at a concentration of 0.3 ml/l of water. This treatment proved to be highly effective and superior in minimizing fruit damage, which was recorded at 4.83%, and also resulted in a higher yield of 18.16 t/ha. The efficacy of spinosad was attributed to its toxic effects through ingestion and rapid contact with the flies.

In their study aimed at controlling fruit flies infesting ridge gourds, Dubale et al. (2018) evaluated the effectiveness of six insecticides. After conducting three spray applications and calculating the total average results, they found that Spinosad 45 SC at a concentration of 0.014% exhibited the best performance, resulting in the lowest mean fruit infestation rate of 23.55%.

Sharma (2018), conducted a study to assess the effectiveness of various biopesticides in comparison to the recommended pesticide, which is malathion, for controlling pests in mango and peach orchards. The findings of the study revealed that the application of spinosad yielded the lowest levels of fruit infestation. Following closely behind in terms of efficacy were azadirachtin and *B. bassiana*.



Materials and methods

Chapter – 3

MATERIALS AND METHODS

The research work of the present investigations entitled “Seasonal incidence, biology and management of peach fruit fly under low hills conditions of Himachal Pradesh” was carried out in the Department of Entomology, College of Horticulture and Forestry, Neri (Hamirpur), Himachal Pradesh.

3.1. Seasonal abundance of fruit flies in the low & Shivalik hills of Himachal Pradesh.

3.1.1. Monitoring and trapping of fruit fly using Male Annihilation Technique (MAT).

The male annihilation technique is an approach used to control fruit flies by eliminating male individuals, thereby decreasing their ability to mate, resulting in a reduced number of offspring produced by females. This technique involves combining methyl eugenol with an insecticide, which is infused into a suitable material to create an effective substrate for fruit fly control.

The experiment was conducted at peach block of the college. To carry out the experiment, small plywood pieces known as septa, measuring $8 \times 2 \times 1.8 \text{ cm}^3$, were immersed in a solution containing 4ml of methyl eugenol, 6ml of ethanol, and 1ml of spinosad. The septa were left overnight to ensure complete saturation. Subsequently, the saturated septa were placed inside bottle traps that were locally constructed. On each side of the trap, four holes were created to allow the entry of fruit flies. The abundance of fruit flies was monitored from April 2022 to May 2023.

3.1.2. Relation of fruit fly incidence with weather parameters

Weather data on temperature, relative humidity and rainfall were taken from the records maintained by the Department of soil science, College of Horticulture and Forestry, Neri, Hamirpur. From the data on maximum temperature, minimum temperature, relative humidity and rainfall, correlation between fruit fly incidence and weather parameters was worked out.

3.2. To study biology of fruit fly infesting peach in low hills of Himachal Pradesh.

In order to study the biology of the fruit fly, observations were conducted at an experimental farm located in the College of Horticulture and Forestry, Neri, Hamirpur. The fruit fly culture was initially established and maintained in the laboratory of the Department of

Entomology. Infested peach fruits were collected from the experimental area of the Neri farm for the study.

3.2.1. Maintenance of culture

After regular checks for infested fruits at the peach farm, the infested fruits were collected and kept in a plastic tray with a 5 cm layer of moist, sieved sand to aid in pupation. The rotten peach fruits from the plastic trays were taken out, and sand was sieved to gather pupa. The collected pupae were placed into separate cages for further observation. The newly emerged male and female adult fruit flies were placed in rearing cages, where they were provided with a semisolid diet consisting of protein hydrolysate contained in plastic petri dishes. To facilitate adult feeding, a sponge soaked in a 5% honey solution was placed inside the rearing cage. After mating, the adult fruit flies deposited their eggs in the fresh peach fruits placed within the rearing cage. The fruits with freshly laid eggs were then used for the study of biology.

3.2.1.1. Eggs

To analyse the shape, size, and colour of the eggs, microscopic examination was conducted. The length and width of the eggs were measured in millimetres using digital Vernier callipers. For studying the average incubation period, ten freshly laid eggs were observed each morning until hatching occurred. When tiny maggot came out from egg, then it was considered as hatched egg.

3.2.1.2. Maggot period

Ten freshly hatched maggots were kept in petri dish and were reared on fresh peach pieces. Maggots were reared till they suspended feeding and thereafter transferred to the sand layer of about 5 cm depth, placed in a plastic tray. Sand was sieved daily for collection of pupae to determine the maggot period. Maggot period was taken as the duration from egg hatching to pupal formation.

3.2.1.3. Prepupal & pupal period

The 3rd instar maggot suspended feeding, stopped movements, and became sluggish before ecdysis to pupation. The prepupal period was recorded as the time period between inactivation and ecdysis to pupal stage. The pupa collected from the sand, were transferred individually into glass vials (12.5 × 4cm). The muslin cloth was used to cover the open end of the vials held in position by rubber band and under 3 cm thick sand layer, pupae were placed

carefully. To avoid desiccation of pupae, sand was moistened by water. Pupae were watched daily, till adult emergence to ascertain the pupal period.

3.2.1.4. Pre-oviposition and oviposition period.

Ten mated females were used to record the pre-oviposition period as the time period from adult emergence to initiation of egg laying. Daily observations were taken on the egg laying on the ripe peach fruits by such mated females and the oviposition period was recorded as the duration from initiation of egg laying till its termination.

3.2.1.5. Sex ratio

Sex ratio means total number of male and female fruit flies emerged out from the same lot of pupae. Twenty pupae were collected from the laboratory raised culture and subsequently watched for adult emergence. On the presence or absence of ovipositor and their abdomen size, sexes of flies were determined.

3.2.1.6. Adult longevity

Adult longevity was recorded as the time period from the emergence of adults from the pupae till their death. Adult longevity was determined on the diet of honey + water.

3.3. Management.

3.3.1. Evaluation of different Male Annihilation Techniques (MATs) for catches of fruit fly species.

Male annihilation technique (MAT) is a fruit fly control method used to reduce the chances of mating and kill male flies. So, the progeny produced by females is very little. Consequently, wild population in the target area declined. To eradicate the fruit fly, MAT can be successfully used. Methyl eugenol along with an insecticide impregnated into a suitable substrate forms the basis of male annihilation technique.

For carrying out this experiment plywood pieces (called as septa) of different sizes were soaked in solutions to be tested and to complete saturation of the septa, these pieces were kept overnight. These septa were placed in locally made bottle traps. Four holes were made on each side of the trap for entry of the fruit flies. The observations were recorded at Peach block of the College.

3.3.1.1. Installation of fruit fly traps.

The septa were tied with the binding wire so that they remain suspended near the lid of the trap and could not fall down to the base of the trap, otherwise rainwater in the trap may dilute the effect of chemicals soaked in the septa. The binding wire was passed through the lid and traps were hung on the experimental trees.

3.3.1.2. Preparation of septa impregnated with methyl eugenol

Plywood pieces were dipped in hot water for cleaning and were then dried at room temperature. Plywood pieces 8 cm × 2 cm × 1.8 cm and 4 cm × 2 cm × 1.8 cm were soaked in different combinations of chemicals (methyl eugenol, ethanol, malathion, cypermethrin, indoxacarb, cyantraniliprole and spinosad) solutions and kept overnight for complete saturation. These septa were then placed in traps.

The different treatments were evaluated for following observations of male annihilation technique:

1. No. of fruit flies catches in each treatment.
2. Duration of longevity of each trap.

Table 3.1. Details of treatments used for the evaluation of MAT's-

Treatment	Chemicals in Septa
T ₁	Methyl Eugenol (4ml) + Ethanol (6ml) + Cypermethrin (1ml)
T ₂	Methyl Eugenol (4ml) + Ethanol (6ml) + Spinosad (1ml)
T ₃	Methyl Eugenol (2ml) + Ethanol (3ml) + Indoxacarb (0.5ml)
T ₄	Methyl Eugenol (2ml) + Ethanol (3ml) + Spinosad (0.5ml)
T ₅	Methyl Eugenol (2ml) + Ethanol (3ml) + Cyantraniliprole (0.5ml)
T ₆	Methyl Eugenol (4ml) + Ethanol (6ml) + Malathion (1ml)

*Each Treatment was replicated thrice

Septa size used for treatments T₁-T₃ was 8 cm × 2 cm × 1.8 cm and same for treatments



A. Soaking of septa

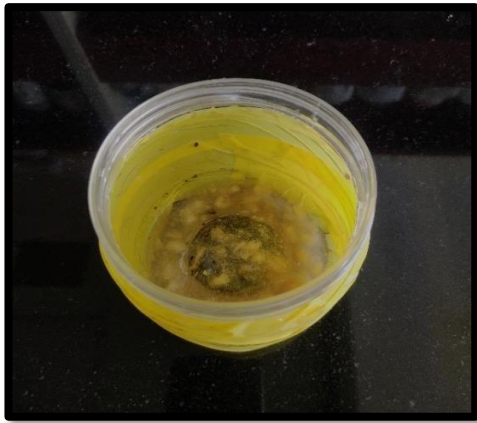


B. Septa size: $8*2*1.8\text{ cm}^3$

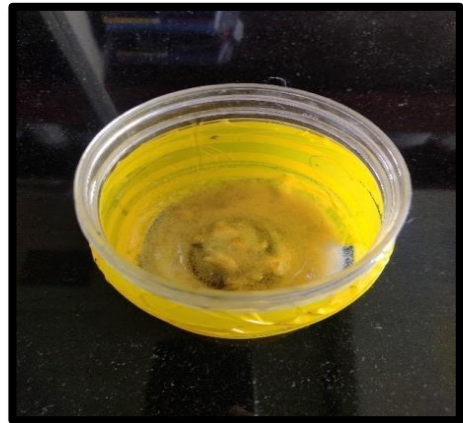


C. Septa size: $4*2*1.8\text{ cm}^3$

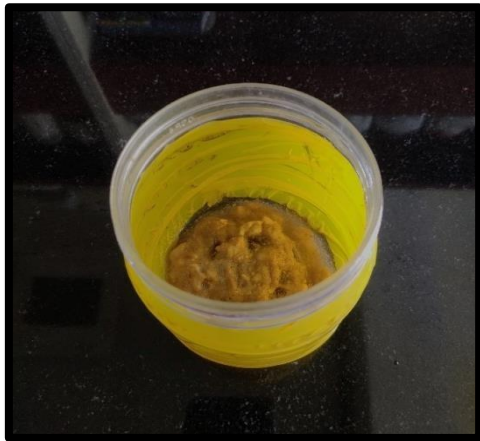
PLATE 1. Different septa used in MAT's



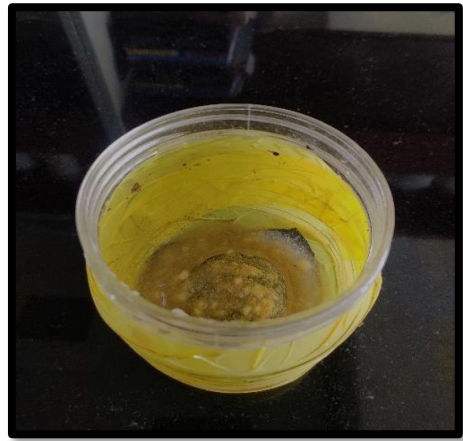
A. BAIT 1



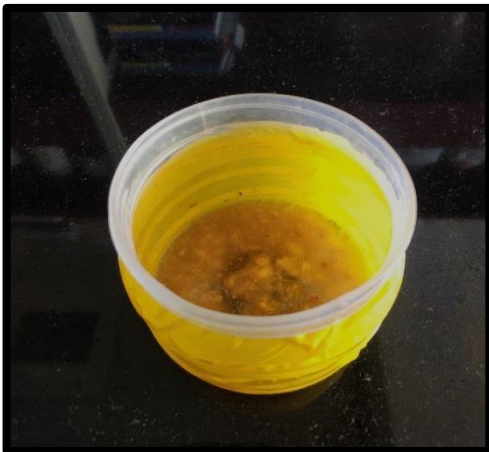
B. BAIT 2



C. BAIT 3



D. BAIT 4



E. BAIT 5



F. BAIT 6

PLATE 2. Different baits used

T4-T6 was 4 cm × 2 cm × 1.8 cm. All the 7 treatments were replicated thrice under Randomized Block Design. Treatment T6 was taken as control, against which all other treatments were compared.

3.3.2. Efficacy of different bait mixtures against fruit fly.

The attraction of fruit flies to different baits containing insecticides was assessed in traps containing different bait mixtures.

3.3.2.1. Preparation of Baits.

Various combinations of fruit pulp were mixed together, as outlined in Table 3.2. The resulting semi-solid liquid was then placed inside the traps, which were locally constructed as mentioned earlier. These traps were hung close to the canopy of the trees. Baits were changed, once in a week. Traps were cleaned periodically.

Table 3.2. Details of different baits evaluated for catch of different fruit fly species

Treatment	Material required
T ₁	Casein + Sugar + Banana pulp (1:1:1) + 5% ammonium acetate
T ₂	Soya powder + Sugar + Guava pulp (1:1:1) + 5% ammonium acetate
T ₃	Yeast + Sugar + Guava pulp (1:1:1) + 5% ammonium acetate
T ₄	Sugar + Guava pulp (1:1) + 5% ammonium acetate
T ₅	Yeast + Sugar + Banana pulp (1:1:1) + 5% ammonium acetate
T ₆	Malathion (1ml) + Jaggery (10g) + Water (10ml)

*Each treatment was replicated thrice.

All the 6 baits were replicated thrice under Randomized Block Design. Treatment T6 was taken as control, against which all other treatments were compared.

3.3.3. Evaluation of synthetic insecticides and some botanicals

The studies on the management of the fruit fly were carried out at Neri, Hamirpur. The

experiment was laid out in the Randomized Block Design with three replications. The peach farm was regularly visited for the observations like initiation of flowering and infestation by the fruit fly. The details of the test insecticides/botanicals used in the present studies are presented in Table 3.3.

Table 3.3. Details of insecticides/botanicals used against fruit fly

Treatments	Chemical / Botanical	Formulation	Trade Name
T ₁	Spinosad	45%SC	Tracer
T ₂	Cyantraniliprole	10.26%OD	Benevia
T ₃	Cypermethrin	25%EC	Superkill
T ₄	Chlorantraniliprole	18.5%SC	Coragen
T ₅	Agni Astra	-	-
T ₆	NSKE	-	Strike Plus
T ₇	Water (Control)	-	-

3.3.3.1. Preparation of Agniastra-

For the preparation of Agniastra following ingredients were used as shown in Table 3.4:

Table 3.4 Ingredients of Agniastra.

Sr. No.	Ingredient	Quantity
1.	Cow urine	20L
2.	Garlic	½ kg
3.	Green chilies	½ kg
4.	Neem leaves	5kg
5.	Tobacco leaves	100g

All these ingredients were boiled in a pan for about 30 minutes. After boiling, this mixture was kept undisturbed for 48 hours and liquid was extracted from it and solid waste was decomposed. Agniastra was then ready to use.



PLATE 3. Agniastra

Table 3.5. Concentrations of different insecticides/botanicals applied for the management of fruit fly

Treatments	Chemical / Botanical	Concentration (%)
T ₁	Spinosad 45%SC	0.004
T ₂	Cyantraniliprole 10.26%OD	0.002
T ₃	Cypermethrin 25%EC	0.0075
T ₄	Chlorantraniliprole 18.5%SC	0.005
T ₅	Agni Astra	2.0
T ₆	NSKE	5.0
T ₇	Water (Control)	No spray

*Each treatment was replicated thrice.

The experimental farm was visited regularly for the observations like initiation of flowering and infestation by fruit fly. Each treatment was replicated thrice in Randomized Block Design.

The schedule of different sprays is given below.

1. First Spray: At walnut stage.
2. Second Spray: At maturity.

Data were recorded on the infestation of fruit fly after 7, 14 days of each spray.

Per cent fruit infestation in each treatment was worked out by the formula:

$$\text{Per cent fruit infestation} = (\text{No. of fruits infested} / \text{Total no. of fruits}) \times 100$$

Statistical analysis

Statistical analysis was conducted on the data collected in field conditions to determine the significance of the obtained results. The data were analysed using Randomized Block Design as suggested by Gomez and Gomez (1986).



Results and discussion



Chapter – 4

RESULTS AND DISCUSSION

This chapter presents the outcomes of the ongoing research conducted on "**Seasonal incidence, biology, and management of the peach fruit fly under low hills conditions of Himachal Pradesh.**" The current discoveries are also connected with findings from related research conducted at another place.

4.1. Seasonal incidence of fruit fly under low hills conditions of Himachal Pradesh.

4.1.1. Supervision and capture of fruit fly employing the Male Annihilation Technique (MAT).

The current study involved a survey carried out over two consecutive years, namely 2022 and 2023, with the aim of evaluating the diversity of fruit flies on peach trees. The tephritid fruit fly is a globally distributed pest, with a notable presence in Asian nations like India. Within Himachal Pradesh, this insect holds significant concern as a damaging phytophagous pest due to factors such as its wide dispersion, invasive tendencies, and its capacity to cause economic harm to fruit and vegetable cultivation. Numerous fruits and vegetables have been documented as susceptible hosts, such as guava, mango, peach, citrus, tomato, and various cucurbits. The presence of this pest leads to the decay and premature dropping of infested fruits, causing degradation in both the yield and the quality of the produce. The significance of monitoring lies in documenting variations in fruit fly population levels and enacting essential control strategies. The dynamics of the pest population are predominantly shaped by diverse meteorological factors. These meteorological factors proves beneficial in analysing the upsurge of the pest population, thereby aiding in predictions and the timely implementation of measures.

The investigation was conducted on a peach farm situated at the College of Horticulture and Forestry in Neri, Hamirpur. To achieve this, three fruit fly traps, infused with a methyl-eugenol solution, were strategically positioned within the farm. The fruit flies captured by these

traps were observed on a monthly basis throughout the entire year. The collected data has been organized and is displayed in Table 4.1.

Table 4.1. Seasonal abundance of fruit fly species that affect fruit crops in Neri, Hamirpur, across various months in the period spanning (2022 to 2023)

Month	No. of fruit flies/trap/month				
	<i>B. dorsalis</i>	<i>B. zonata</i>	Others	Total	Average
April, 2022	188.33	125.67	68.33	382.33	127.44
May, 2022	206.33	143.67	79.33	429.33	143.11
June, 2022	168.33	110.67	61.33	340.33	113.44
July, 2022	224.33	170.67	91.67	486.67	162.22
August, 2022	252.33	196.67	105.33	554.33	184.78
September, 2022	241.33	183.67	98.33	523.33	174.44
October, 2022	103.67	57.33	32.67	193.67	64.56
November, 2022	64.67	41.33	18.33	124.33	41.44
December, 2022	43.33	24.67	15.33	83.33	27.78
January, 2023	6.33	2.67	2.33	11.33	3.78
February, 2023	7.67	4.33	8.33	20.33	6.78
March, 2023	14.33	7.67	10.33	32.33	10.78
April, 2023	219.67	167.33	84.33	471.33	157.11
May, 2023	305.67	216.33	125.67	647.67	215.89
Total	2046.33	1452.67	801.67	4300.67	1433.56
C.D.	52.90				

*Each observation is an average of 3 replications.

**Among other species, *B. scutellaris* dominated the population.

The average peak population of *Bactrocera spp.* was observed in May, 2023 (215.89), followed by August (184.78) and September (174.44). The average lowest population of *Bactrocera spp.* was observed in January 2023 (3.78), followed by February 2023 (6.78) and March 2023 (10.78). On average, *Bactrocera dorsalis* exhibited a higher population (2046.33 per trap per year) compared to *Bactrocera zonata* (1452.67 per trap per year).



A. Traps used in monitoring



B. Traps installed in field



C. Flies trapped

PLATE 4. Traps used in monitoring for seasonal abundance

According to Mahmood and Mishkatuallah (2007) the peak population of *Bactrocera zonata* was observed during July and August months and showed a low population level from November to February. Ravikumar (2005) who reported *B. zonata* had a major peak during last week of May. Mahmood et al. (2002) also reported that from May to July months was the highest trapping period of *B. zonata*. According to Khan and Naveed (2017) the minimum population of *Bactrocera zonata* was observed in the month of November, December, January, and February, respectively. Hence, the present data is in accordance with the findings of these workers. The variation in the results might be due to the weather parameters prevailing in that locality, fruiting period, time of harvest of fruits.

Table 4.2. Seasonal incidence of peach fruit fly with relation to weather parameters

Month	Average	Average relative humidity (%)	Total Rainfall (mm)	Average Max. Temperature (°C)	Average Min. Temperature (°C)
April,2022	127.44	27.37	4.56	37.8	23.23
May,2022	143.11	29.56	59.13	39.42	25.92
June,2022	113.44	33.73	90.13	40.04	27.67
July,2022	162.22	77.21	494.17	32.51	26.07
August,2022	184.78	84.31	359.73	30.89	24.89
September,2022	174.44	81.00	190.29	29.99	23.47
October,2022	64.56	68.30	43.62	27.85	18.91
November,2022	41.44	58.01	9.08	24.72	14.79
December,2022	27.78	38.28	4.09	22.91	11.18
January,2023	3.78	50.29	149.12	19.42	8.63
February,2023	6.78	44.28	2.33	25.14	12.15
March,2023	10.78	51.22	80.00	26.87	15.39
April,2023	157.11	45.83	116.59	31.32	17.89
May,2023	215.89	55.67	176.81	31.84	20.66

4.1.2. Correlation study of fruit fly incidence with weather parameters

The correlation coefficient between the average number of fruit flies and the weather parameters, was worked out as shown in Table 4.3. The results of the correlation analysis between the average number of fruit flies and the weather factors under investigation indicated

that average number of fruit flies were positively and non- significantly correlated with relative humidity (0.31). However, average number of fruit flies were positively and significantly correlated with rainfall (0.56), average maximum temperature (0.66) and average minimum temperature (0.78).

Table 4.3. Correlation study of fruit fly incidence with weather parameters

Weather parameters	Correlation coefficient
Relative humidity	0.311 ^{NS}
Rainfall	0.560*
Maximum temperature	0.660*
Minimum temperature	0.788**

*Significant at 1% level of significance

** Significant at 5% level of significance

^{NS} Non- significant

4.1.3. Multiple regression equation

Table 4.4. Multiple regression equation indicating correlation of fruit fly incidence with weather parameters

Multiple regression value	R ²	Coefficient of multiple determination (%)
$Y = -604.491 + 3.963X_1 + 0.159X_2 + 28.398X_3 - 19.519X_4$	0.7581	75.81

X₁ = Relative humidity, X₂ = Rainfall, X₃ = Maximum temperature, X₄ = Minimum temperature and Y = Average number of fruit fly

The multiple coefficient of determination for the average fruit fly population in relation to the independent variables was found to be 0.7581. This suggests that 75.81% of the variation in the fruit fly population was attributed by all the weather parameters considered in the study

collectively. The remaining variation is attributed to factors that were not included in the investigation.

4.2. Biology of *Bactrocera zonata*

The research was conducted under laboratory conditions, and Tables 4.5 and 4.6 were used to present data related to morphometric studies and the durations of various life stages of fruit fly.

4.2.1. Egg

The egg of *Bactrocera zonata* is characterized by its slender, curved shape, tapering at one end, and initially appearing shiny white but gradually transitioning to a creamy yellow as it approaches the hatching period. The morphometric analysis revealed that the length of *Bactrocera zonata* eggs ranged from 1.0 to 1.2 mm, with a mean length of 1.10 ± 0.03 mm and width of eggs ranging from 0.15 to 0.2 mm, with an average width of 0.17 ± 0.01 mm.

Mir et al. (2015) found eggs to be 1.0 ± 0.04 mm long with a range of 1.0-1.1 mm and 0.2 ± 0.0 mm wide with a range of 0.2-0.2 mm.

4.2.1.1. Incubation period

The incubation duration spanned from 1 to 2 days, with an average period of 1.67 ± 0.13 days.

These findings align with the observations made by Khattak et al. (2012), who noted that the eggs hatched within a two-day timeframe. Hosni et al. (2011) reported that eggs had an incubation period that varied from 1 to 3 days, with an average duration of 2.7 days.

4.2.2. Maggot

4.2.2.1 Number of instars

Under laboratory conditions, it was observed that the larvae of *Bactrocera zonata* developed through three instars.

4.2.2.2 First instar

The newly hatched first-instar larvae are elongated and white. The larva's anterior end is slender and pointed, while the posterior end is somewhat rounded and broader. In the head

region, there are small mouth hooks that appear yellowish-brown in colour. The first instar larvae exhibited variations in both their length and breadth, ranging from 1.5-2.3 mm in length with an average of 1.76 ± 0.10 mm, and from 0.2-0.5 mm in width with an average of 0.33 ± 0.04 mm. The duration of the first instar phase showed variability, spanning from 1.0-2.5 days, with an average duration of 1.92 ± 0.17 days.

4.2.2.3 Second instar

The second instar larvae appeared as creamy white, elongated, ellipsoidal, and translucent. Notably, this larval stage is identified by the presence of anterior spiracles. The length of second instar larvae ranged from 4.1-6.5 mm and an average of 5.04 ± 0.34 mm, while the width ranged from 0.9-1.3 mm, with an average of 1.09 ± 0.05 mm. The duration of the second instar phase ranged from 1.5-3.0 days with an average duration of 2.5 ± 0.18 days, as indicated in Table 4.6.

4.2.2.4 Third instar

The third instar larvae appeared elongated and had a dark yellowish colour. They were characterized by prominently sclerotized mouth hooks and a distinctive jumping behaviour. The length of third instar larvae ranged from 9.0-10.3 mm and an average of 9.56 ± 0.17 mm, while the width ranged from 1.5-2.0 mm, with an average of 1.76 ± 0.06 mm. The duration of the third instar phase ranged from 3.5-4.0 days with an average duration of 3.75 ± 0.06 days, as indicated in Table 4.6.

4.2.3. Pupa

The pupa of *Bactrocera zonata* pupate in sand under laboratory conditions and in soil under field conditions. The pupae were cylindrical with eleven segments and initially appeared deep brownish-yellow upon formation. Over time, their colour transformed into a dark reddish-brown to ochraceous shade.

The length of pupa ranged from 4.1-5.0 mm and an average of 4.56 ± 0.10 mm, while the width ranged from 2.1-2.5 mm, with an average of 2.30 ± 0.05 mm. The duration of the pupal phase ranged from 7 to 10 days with an average duration of 8.6 ± 0.38 days.

Murtaza et al. (2021) examined the dimensions of *B. zonata* pupae and reported that the length was approximately 3.54 ± 0.03 mm, while the width measured around 1.00 ± 0.01 mm. According to Khattak et al. (2012) pupal period ranged from 11-13 days.

4.2.4. Adult

Adults are reddish-brown in colour with distinct yellow markings on their thorax. The size of female flies is larger than that of males. Female flies were readily distinguishable from males by the presence of an ovipositor located at the posterior end of their abdomen. The wings display a clear pattern of alternating dark and light bands.

Table 4.5 Morphometrics of different life stages of *Bactrocera zonata* Saunders

Stages	Length (mm)		Width (mm)	
	Range	Mean \pm SE	Range	Mean \pm SE
Egg	1.0-1.2	1.10 ± 0.03	0.15-0.2	0.17 ± 0.01
1 st instar	1.5-2.3	1.76 ± 0.10	0.2-0.5	0.33 ± 0.04
2 nd instar	4.1-6.5	5.04 ± 0.34	0.9-1.3	1.09 ± 0.05
3 rd instar	9.0-10.3	9.56 ± 0.17	1.5-2.0	1.76 ± 0.06
Pupa	4.1-5.0	4.56 ± 0.10	2.1-2.5	2.30 ± 0.05
Adult Male	6.9-8.1	7.37 ± 0.14	9.6-10.5	10.18 ± 0.09
Adult Female	7.1-9.0	7.80 ± 0.22	10.2-12.0	10.90 ± 0.18

*Width with expanded wings

Values are average of 10 observations.

SE = Standard error

4.2.4.1. Male

The dimensions of adult male flies, including their length and width (represented by wing expanse), exhibited a range of 6.9-8.1 mm in length, with an average of 7.37 ± 0.14 mm, and 9.6-10.5 mm in width, with an average of 10.18 ± 0.09 mm.

The male flies had a lifespan ranging from 15-24 days, with an average duration of 20.8 ± 0.98 days.

4.2.4.2. Female

The dimensions of adult female flies, including their length and width (represented by wing expanse), exhibited a range of 7.1-9.0 mm in length, with an average of 7.80 ± 0.22 mm, and 10.2-12.0 mm in width, with an average of 10.90 ± 0.18 mm.

The female flies had a lifespan ranging from 18-30 days, with an average duration of 26.3 ± 1.49 days.

4.2.5. Pre-oviposition period

The pre-oviposition period of *Bactrocera zonata* female fruit fly ranged from 9 to 13 days, with an average duration of 11.3 ± 0.49 days, as indicated in Table 4.6.

4.2.6. Oviposition period

The oviposition period of *Bactrocera zonata* female fruit fly varied from 3 to 8 days with an average duration of 6.00 ± 0.61 days, respectively.

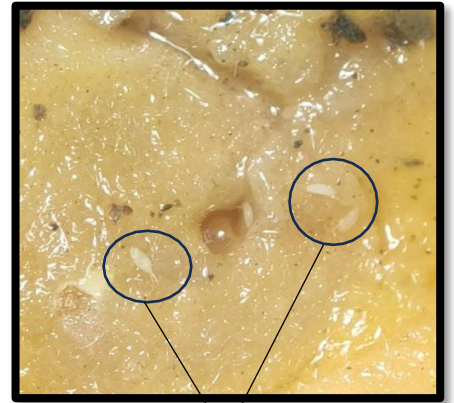
4.2.7. Post-oviposition period

The post-oviposition period of *Bactrocera zonata* female fruit fly spanned from 4 to 7 days with an average duration of 4.5 ± 0.48 days, respectively.

The post-oviposition period data were more or less similar to that of Abu-Ragheef and Al-Jassany (2018), who found post-oviposition period to be 4.2 days at $30 \pm 2^\circ\text{C}$, 9.4 days at $20 \pm 2^\circ\text{C}$ (when the larvae fed on an artificial diet), and 5.3 days under field conditions.



A. Female laying eggs



B. Eggs



C. Maggots



D. Pupa



D. Male



E. Female

PLATE 5. Developmental stages of fruit fly, *Bactrocera zonata*

Table 4.6 Duration of different life stages of *Bactrocera zonata* Saunders

Stages	Range (days)	Mean \pm SE (days)
Incubation period	1.0-2.0	1.67 \pm 0.13
1st instar	1.0-2.5	1.92 \pm 0.17
2nd instar	1.5-3.0	2.5 \pm 0.18
3rd instar	3.5-4.0	3.75 \pm 0.06
Pupa	7.0-10	8.6 \pm 0.38
Pre-Oviposition period	9.0-13	11.3 \pm 0.49
Oviposition period	3.0-8.0	6.00 \pm 0.61
Post-Oviposition period	4.0-7.0	4.5 \pm 0.48
Male longevity	15.0-24.0	20.8 \pm 0.98
Female longevity	18.0-30.0	26.3 \pm 1.49
Sex ratio (male: female)	1:1.2	

Values are average of 10 observations. **SE = Standard Error

4.2.8. Total development period

The life cycle of *B. zonata*, from egg to adult emergence, typically spans a range of 14-21.5 days, with an average duration of 17.6 \pm 0.90 days. Hosni et al. (2011) stated that total development period of peach fruit fly is 18.7 days.

4.2.9. Sex Ratio

The sex ratio for *Bactrocera zonata* was recorded as 1:1.2 (male: female).

These findings were somewhat consistent with those of Rana et al. (1992) who documented a ratio of 1:1.1 and Khattak et al. (2012), who reported a ratio of 1:0.95.

4.3. Management

4.3.1. Male Annihilation Techniques (MATs)

The male annihilation technique involves the use of traps containing a male attractant paired with an insecticide. This method aims to significantly diminish the male fruit fly population, preventing mating and consequently disrupting the reproductive cycle.

4.3.1.1. Assessing different methods of Male Annihilation Techniques (MATs) in April 2023

The results of the evaluation of various male annihilation techniques (MATs) in April are summarized in Table 4.7. Six different treatments were assessed for their effectiveness in capturing fruit flies. Out of the six treatments that were tested for fruit fly capture, T₆ served as the standard/control method consists of methyl eugenol (4ml) + ethanol (6ml) + malathion (1ml) demonstrated the average highest adult fruit fly captures (174.50 fruit flies/trap/week), followed by T₂ - methyl eugenol (4ml) + ethanol (6ml) + spinosad (1ml) (107.69 fruit flies/trap/week) and T₄ - methyl eugenol (2ml) + ethanol (3ml) + spinosad (0.5ml) (97.31 fruit flies/trap/week), respectively, which were significantly higher as compared to other treatments. T₃ which consisted of methyl eugenol (2ml) + ethanol (3ml) + indoxacarb (0.5ml), exhibited the lowest captures, specifically (25.89 fruit flies/trap/week), followed by T₁, comprising methyl eugenol (4ml) + ethanol (6ml) + cypermethrin (1ml) i.e. (66.83 fruit flies/trap/week). The table clearly indicates that, on average, *Bactrocera dorsalis* was the most predominant species, with a capture rate of 120.76 fruit flies/trap/week. This was followed by *Bactrocera zonata* at 87.83 fruit flies/trap/week and *Bactrocera scutellaris* at 72.07 fruit flies/trap/week.

The highest population of *Bactrocera dorsalis* was observed in treatment T₆, with a capture rate of 240.50 fruit flies/trap/week, followed by T₂ at 133.83 fruit flies/trap/week, and T₄ at 120.08 fruit flies/trap/week. The lowest population of *Bactrocera dorsalis* was recorded in T₃, with only 36.42 fruit flies/trap/week, followed by T₁, which had 88.42 fruit flies/trap/week. A similar pattern was noticed for *Bactrocera zonata* and *Bactrocera scutellaris*. However, the average population of *Bactrocera zonata* was higher than that of *Bactrocera scutellaris* among various treatments.



A. Bait traps



B. MAT traps

PLATE 6. Different traps installed in field

Table 4.7 Evaluation of different Male Annihilation Techniques (MATs) during April 2023 at Neri

Treatments		Catches of fruit fly/trap/month			Mean
		<i>Bactrocera dorsalis</i>	<i>Bactrocera zonata</i>	<i>Bactrocera scutellaris</i>	
T ₁	Methyl eugenol (4ml) + Ethanol (6ml) + Cypermethrin (1ml)	88.42	61.42	50.67	66.83
T ₂	Methyl eugenol (4ml) + Ethanol (6ml) + Spinosad (1ml)	133.83	102.08	87.17	107.69
T ₃	Methyl eugenol (2ml) + Ethanol (3ml) + Indoxacarb (0.5ml)	36.42	22.67	18.58	25.89
T ₄	Methyl eugenol (2ml) + Ethanol (3ml) + Spinosad (0.5ml)	120.08	92.50	79.33	97.31
T ₅	Methyl eugenol (2ml) + Ethanol (3ml) + Cyantraniliprole (0.5ml)	105.33	83.83	78.17	89.11
T ₆	Methyl eugenol (4ml) + Ethanol (6ml) + Malathion (1ml)	240.50	164.50	118.50	174.50
	Mean	120.76	87.83	72.07	

*Mean of 3 replications **T₆ = Standard (Control)

T₁–T₃ = septa size 8 cm × 2 cm × 1.8 cm

T₄–T₆ = septa size 4 cm × 2 cm × 1.8 cm

C.D.

Treatments – 0.92

Species – 0.65

T X S – 1.60

4.3.1.2. Assessing different methods of Male Annihilation Techniques (MATs) in May 2023

The results of the evaluation of various male annihilation techniques (MATs) in May are summarized in Table 4.8. Six different treatments were assessed for their effectiveness in capturing fruit flies. Out of the six treatments that were tested for fruit fly capture, T₆, served as the standard/control method consists of methyl eugenol (4ml) + ethanol (6ml) + malathion (1ml) demonstrated the average highest adult fruit fly captures (199.36 fruit flies/trap/week), followed by T₂ - methyl eugenol (4ml) + ethanol (6ml) + spinosad (1ml) (138.22 fruit flies/trap/week) and T₄ - methyl eugenol (2ml) + ethanol (3ml) + spinosad (0.5ml) (112.97 fruit flies/trap/week), respectively, which were significantly higher as compared to other treatments. T₃ which consisted of methyl eugenol (2ml) + ethanol (3ml) + indoxacarb (0.5ml), exhibited the lowest captures, specifically (36.47 fruit flies/trap/week), followed by T₁, comprising methyl eugenol (4ml) + ethanol (6ml) + cypermethrin (1ml) i.e. (73.53 fruit flies/trap/week). The table clearly indicates that, on average, *Bactrocera dorsalis* was the most predominant species, with a capture rate of 148.46 fruit flies/trap/week. This was followed by *Bactrocera zonata* at 101.67 fruit flies/trap/week and *Bactrocera scutellaris* at 79.39 fruit flies/trap/week.

The highest population of *Bactrocera dorsalis* was observed in treatment T₆, with a capture rate of 294.17 fruit flies/trap/week, followed by T₂ at 196.08 fruit flies/trap/week, and T₄ at 145.08 fruit flies/trap/week. The lowest population of *Bactrocera dorsalis* was recorded in T₃, with only 49.67 fruit flies/trap/week, followed by T₁, which had 93.17 fruit flies/trap/week. A similar pattern was noticed for *Bactrocera zonata* and *Bactrocera scutellaris*. However, the average population of *Bactrocera zonata* was higher than that of *Bactrocera scutellaris* among various treatments.

The Male Annihilation Technique (MAT), employing male lures, stands out as the most widely accepted and effective approach for fruit fly control, as supported by research from Vargas et al. in 2009 and Tan et al. in 2014. It eliminates male flies, diminishing their ability to mate, subsequently resulting in a significant reduction in the production of offspring by females. Consequently, this approach leads to a decline in the fruit fly population within the targeted area, ultimately contributing to eradication.

Table 4.8 Evaluation of different Male Annihilation Techniques (MATs) during May 2023 at Neri

Treatments		Catches of fruit fly/trap/month			Mean
		<i>Bactrocera dorsalis</i>	<i>Bactrocera zonata</i>	<i>Bactrocera scutellaris</i>	
T ₁	Methyl eugenol (4ml) + Ethanol (6ml) + Cypermethrin (1ml)	93.17	75.50	51.92	73.53
T ₂	Methyl eugenol (4ml) + Ethanol (6ml) + Spinosad (1ml)	196.08	117.83	100.75	138.22
T ₃	Methyl eugenol (2ml) + Ethanol (3ml) + Indoxacarb (0.5ml)	49.67	33.08	26.67	36.47
T ₄	Methyl eugenol (2ml) + Ethanol (3ml) + Spinosad (0.5ml)	145.08	101.42	92.42	112.97
T ₅	Methyl eugenol (2ml) + Ethanol (3ml) + Cyantraniliprole (0.5ml)	112.58	93.75	89.08	98.47
T ₆	Methyl eugenol (4ml) + Ethanol (6ml) + Malathion (1ml)	294.17	188.42	115.50	199.36
	MEAN	148.46	101.67	79.39	

*Mean of 3 replications **T₆ = Standard (Control)

T₁–T₃ = septa size 8 cm × 2 cm × 1.8 cm

T₄–T₆ = septa size 4 cm × 2 cm × 1.8 cm

C.D.

Treatments – 0.68

Species – 0.48

T X S – 1.19

In our current research, we observed that ply board septa treated with ethanol solvent, methyl eugenol, and malathion were highly effective in orchards against fruit flies. This

observation is consistent with the findings of previous studies conducted by Patel et al., 2005, Stonehouse et al. in 2007, and Singh et al. in 2008. Our results demonstrated that ply board septa impregnated with the same substances results the highest fruit fly captures. Therefore, our findings align with those of the above researchers.

In present study, we observed that larger-sized plywood pieces trapped a greater number of flies in comparison to smaller-sized traps. This phenomenon can be attributed to the larger-sized septa's higher capacity for absorbing chemicals compared to small septa. This observation is consistent with the findings of Singh et al. (2017), who similarly noted that large plywood blocks were significantly more effective at trapping flies, followed by medium, small, and extra-small blocks in decreasing order of effectiveness.

4.3.1.3. Assessing different methods of Male Annihilation Techniques (MATs) in June 2023

The results of the evaluation of various male annihilation techniques (MATs) in June are summarized in Table 4.9. Six different treatments were assessed for their effectiveness in capturing fruit flies. Out of the six treatments that were tested for fruit fly capture, T₆, served as the standard/control method consists of methyl eugenol (4ml) + ethanol (6ml) + malathion (1ml) demonstrated the average highest adult fruit fly captures (82.97 fruit flies/trap/week), followed by T₂ - methyl eugenol (4ml) + ethanol (6ml) + spinosad (1ml) (76.92 fruit flies/trap/week) and T₄ - methyl eugenol (2ml) + ethanol (3ml) + spinosad (0.5ml) (66.78 fruit flies/trap/week), respectively, which were significantly higher as compared to other treatments. T₃ which consisted of methyl eugenol (2ml) + ethanol (3ml) + indoxacarb (0.5ml), exhibited the lowest captures, specifically (14.03 fruit flies/trap/week), followed by T₁, comprising methyl eugenol (4ml) + ethanol (6ml) + cypermethrin (1ml) i.e. (35.53 fruit flies/trap/week). The table clearly indicates that, on average, *Bactrocera dorsalis* was the most predominant species, with a capture rate of 64.49 fruit flies/trap/week. This was followed by *Bactrocera zonata* at 55.44 fruit flies/trap/week and *Bactrocera scutellaris* at 45.89 fruit flies/trap/week.

Table 4.9 Evaluation of different Male Annihilation Techniques (MATs) during May 2023 at Neri.

Treatments		Catches of fruit fly/trap/month			Mean
		<i>Bactrocera dorsalis</i>	<i>Bactrocera zonata</i>	<i>Bactrocera spp.</i>	
T ₁	Methyl eugenol (4ml) + Ethanol (6ml) + Cypermethrin (1ml)	41.58	36.17	28.83	35.53
T ₂	Methyl eugenol (4ml) + Ethanol (6ml) + Spinosad (1ml)	86.83	78.67	65.25	76.92
T ₃	Methyl eugenol (2ml) + Ethanol (3ml) + Indoxacarb (0.5ml)	18.75	14.42	8.92	14.03
T ₄	Methyl eugenol (2ml) + Ethanol (3ml) + Spinosad (0.5ml)	76.50	64.33	59.50	66.78
T ₅	Methyl eugenol (2ml) + Ethanol (3ml) + Cyantraniliprole (0.5ml)	70.75	53.58	41.92	55.42
T ₆	Methyl eugenol (4ml) + Ethanol (6ml) + Malathion (1ml)	92.50	85.50	70.92	82.97
	MEAN	64.49	55.44	45.89	

*Mean of 3 replications **T₆ = Standard (Control)

T₁–T₃ = septa size 8 cm × 2 cm × 1.8 cm

T₄–T₆ = septa size 4 cm × 2 cm × 1.8 cm

C.D.

Treatments – 0.74

Species – 0.52

T X S – 1.29

The highest population of *Bactrocera dorsalis* was observed in treatment T₆, with a capture rate of 92.50 fruit flies/trap/week, followed by T₂ at 86.83 fruit flies/trap/week, and T₄ at 76.50 fruit flies/trap/week. The lowest population of *Bactrocera dorsalis* was recorded in

T₃, with only 18.75 fruit flies/trap/week, followed by T₁, which had 41.58 fruit flies/trap/week. A similar pattern was noticed for *Bactrocera zonata* and *Bactrocera scutellaris*. However, the average population of *Bactrocera zonata* was higher than that of *Bactrocera scutellaris* among various treatments.

4.3.2. The effectiveness of different chemicals/botanicals against different species of fruit flies

The current evaluation was conducted at the peach farm of the college with the aim of assessing the efficiency of various insecticides and botanicals against different species of fruit fly. The evaluation involved the application of different treatments to three peach plants. Sprays were done twice of each treatment. Data were gathered by examining the level of fruit infestation among 20 randomly selected fruits within each treatment.

Following the initial spray during the walnut stage, there were no notable infestations observed in any of the treatments. This could be attributed to the fact that the fruits were still immature and firm. As the fruits ripened and became softer, they emitted a distinct odour that attracted fruit flies, leading to an increase in infestations. The table 4.10. data revealed an increase of 51.67 percent in fruit fly infestation within the control group, whereas a decreasing trend was observed in the other treatments after the second spray.

The table clearly demonstrates that treatment T₄ containing chlorantraniliprole (0.005%) exhibited the highest effectiveness with a remarkable reduction of 12.50 percent in infestation, surpassing all other insecticides. Following this, spinosad (0.004%) and cyantraniliprole (0.002%) also showed substantial decreases in infestation i.e., 15.00% and 16.67%. In descending order of effectiveness, the treatments were NSKE (5.0%), agni astra (2.0%), cypermethrin (0.0075%), which exhibited infestation rates of 18.33, 21.67 and 23.33 percent, respectively. NSKE, among the botanical treatments, demonstrated superior with an 18.33 percent infestation rate, as compare to agniastra, which had a 21.67 percent infestation rate. The control, T₇ recorded the highest infestation at 51.67 percent.



PLATE 7. Spraying of insecticides/biopesticides in the experimental field

Table 4.10 Efficacy of different insecticides/botanicals against different species of fruit fly

Treatments	Chemical	Concentration (%)	Average fruit infestation		Total Mean	%infestation
			7 days	14 days		
T ₁	Spinosad 45%SC	0.004	2.33	3.67	3.00	15.00
T ₂	Cyantranilprole 10.26%OD	0.002	2.67	4.00	3.33	16.67
T ₃	Cypermethrin 25%EC	0.0075	4.00	5.33	4.67	23.33
T ₄	Chlorantranilprole 18.5%SC	0.005	2.00	3.00	2.50	12.50
T ₅	Agni Astra	2.0	3.67	5.00	4.33	21.67
T ₆	NSKE	5.0	3.00	4.33	3.67	18.33
T ₇	Water (Control)	-	10.00	10.67	10.33	51.67

* Average of 20 fruits.

C.D. – 0.46

In the context of managing fruit flies in peach orchards, the application of insecticidal treatments in 2009 demonstrated that spinosad, with a fruit infestation rate of 22.9%, outperformed numerous other treatments as reported by Sood and Sharma in 2004, and Oke in 2008. Our findings align with the observations made by Sood and Sharma in 2004, who noted that neem derivatives were statistically better than the untreated control, they proved to be less effective in suppressing infestation compared to synthetic insecticides.

4.3.5. Effectiveness of various bait formulations

4.3.5.1. Assessment of different baits for capturing female fruit flies

Research conducted to assess different baits methods for fruit fly capture across various months. Throughout all three months, Bait 1 (Casein+ Sugar+ Banana pulp 1:1:1+ 5% ammonium acetate) consistently attracted the highest number of female fruit flies, on average

of 15.75 flies/trap in April month, 16.25 flies/trap in May and 14.17 flies/trap in June, followed by Bait 5 (Yeast+ sugar+ banana pulp (1:1:1) + 5% ammonium acetate) with 14.25 flies/trap, 15.25 flies/trap and 13.83 flies/ trap in April, May, and June. The maximum number of female fruit flies was observed in May month followed by April and June.

Our findings indicated that the combination of casein, sugar, and banana pulp captured the highest number of fruit flies per trap per week. These results align with the research by Kumar in 2005, who reported that a diet consisting of protein hydrolysate, sugar, and banana was the most effective protein-based bait, resulting in catches of 15.00 fruit flies per trap per week in guava and 20.50 fruit flies per trap per week in mango. Additionally, when used as 5% of the bait mixture, ammonium acetate attracted a higher number of female fruit flies.

Our current research aligns with the findings of Rajitha and Viraktamath in 2005, who also discovered that baits such as yeast, soybean, fruit fly diet, protein, and casein exhibited a greater preference for females when considering the total fruit fly population. In guava, the most effective protein bait was the combination of casein, sugar, and banana, capturing an average of 14.5 fruit flies per trap per week. Similarly, in mango, the bait consisting of casein, sugar, and papaya attracted a higher number of female fruit flies, with an average capture of 14.33 fruit flies per trap per week.

4.3.5.2. Assessment of different baits for capturing male fruit flies.

Research conducted to assess different baits methods for fruit fly capture across different months. Throughout all three months, Bait 1 (Casein+ Sugar+ Banana pulp (1:1:1) + 5% ammonium acetate) consistently attracted the highest number of male fruit flies, on average of 13.75 flies/trap in April month, 14.25 flies/trap in May and 12.83 flies/trap in June, followed by Bait 5 (Yeast+ sugar+ banana pulp (1:1:1) + 5% ammonium acetate) with 13.25 flies/trap, 12.75 flies/trap and 11.92 flies/ trap in April, May, and June. The maximum number of male fruit flies was observed in May month followed by April and June. Throughout all the months, the female fruit fly population outnumbered the male population.

Table 4.11 Evaluation of various baits for capturing female fruit flies during different months at Neri

	April					May					June				
	1 st week	2 nd week	3 rd week	4 th week	Mean	1 st week	2 nd week	3 rd week	4 th week	Mean	1 st week	2 nd week	3 rd week	4 th week	Mean
Bait 1	13.67	13.00	20.00	16.33	15.75	18.00	11.00	21.00	15.00	16.25	11.00	10.67	16.67	18.33	14.17
Bait 2	9.33	14.00	9.00	11.00	10.83	15.00	13.00	11.00	8.00	11.75	7.33	7.00	11.00	14.67	10.00
Bait 3	11.00	14.00	18.00	12.00	13.75	14.00	17.00	17.00	11.00	14.75	10.33	11.33	14.33	17.67	13.42
Bait 4	10.00	15.00	7.00	19.00	12.75	14.00	18.00	11.00	12.00	13.75	9.67	9.67	13.67	16.33	12.33
Bait 5	11.00	11.00	17.00	18.00	14.25	20.00	17.00	11.00	13.00	15.25	10.67	12.67	14.67	17.33	13.83
Bait 6	9.67	12.67	11.00	16.00	12.33	12.00	15.00	13.00	11.00	12.75	6.67	9.67	11.33	14.67	10.58
Mean	10.78	13.28	13.67	15.39		15.50	15.17	14.00	11.67		9.28	10.17	13.61	16.50	

CD_{0.05}

Months – 0.80

Weeks – 0.92

Months x weeks – 1.60

Treatments – 1.13

Weeks x treatments – 2.26

Months x weeks x treatments – 3.92

Table 4.12 Evaluation of various baits for capturing male fruit flies during different months at Neri

	April					May					June				
	1 st week	2 nd week	3 rd week	4 th week	Mean	1 st week	2 nd week	3 rd week	4 th week	Mean	1 st week	2 nd week	3 rd week	4 th week	Mean
Bait 1	11.00	16.00	11.00	17.00	13.75	19.00	14.00	13.00	11.00	14.25	9.00	11.00	16.00	15.33	12.83
Bait 2	7.00	9.00	7.00	12.00	8.75	10.00	12.00	7.00	10.00	9.75	7.00	9.00	6.67	9.00	7.92
Bait 3	9.00	11.00	11.00	14.00	11.25	15.00	13.00	11.00	10.00	12.25	11.00	7.00	14.00	9.67	10.42
Bait 4	7.00	13.00	10.00	13.00	10.75	10.00	13.00	9.00	13.00	11.25	6.33	9.00	13.33	9.00	9.42
Bait 5	9.00	13.00	17.00	14.00	13.25	14.00	12.00	13.00	12.00	12.75	9.33	14.00	8.33	16.00	11.92
Bait 6	6.33	11.00	9.00	11.00	9.33	9.00	11.00	12.00	9.00	10.25	10.00	7.33	9.33	9.00	8.92
Mean	8.22	12.17	10.83	13.50		12.83	12.50	10.83	10.83		8.78	9.56	11.28	11.33	

CD_{0.05}

Months – 0.76

Weeks – 0.88

Months x weeks – 1.53

Treatments – 1.08

Weeks x treatments – 2.17

Months x weeks x treatments – 3.76.



Summary and conclusion

Chapter – 5

SUMMARY AND CONCLUSION

The research entitled "Seasonal incidence, biology and management of peach fruit fly under low hills conditions of Himachal Pradesh" was conducted in the Department of Entomology at the College of Horticulture and Forestry, Neri, located in Hamirpur, Himachal Pradesh. The research encompassed an investigation into following aspects, including the seasonal incidence of fruit fly, biological and morphometric characteristics, the efficiency of different Male Annihilation Techniques (MATs), bait formulations, and the assessment of various insecticides and botanical solutions. These findings and details have been documented below:

5.1 Seasonal incidence

The peak seasonal fluctuation in the fruit fly population occurred in May 2023, August 2022 and September 2022 following as the subsequent highest months. The minimum population of fruit flies occurred in January followed by February and March.

The correlation coefficient between the average number of fruit flies and the weather parameters, indicated that average number of fruit flies was positively and non-significantly correlated with relative humidity whereas, positively and significantly correlated with rainfall, average maximum temperature and average minimum temperature.

5.2 Biology of *Bactrocera zonata*

The egg of *Bactrocera zonata* is characterized by its slender, curved shape, tapering at one end and shiny white. The morphometric analysis revealed that the length of *Bactrocera zonata* eggs ranged from 1.0 to 1.2 mm, with a mean length of 1.10 ± 0.03 mm and width of eggs ranging from 0.15 to 0.2 mm, with an average width of 0.17 ± 0.01 mm. The incubation duration ranged from 1 to 2 days, with an average period of 1.67 ± 0.13 days. In laboratory conditions, it was determined that larvae underwent three instar stages. The newly hatched first-instar larvae are elongated and white. The second instar larvae appeared as creamy white. The third instar larvae appeared elongated and had a dark yellowish colour.

The average length of first, second and third larvae was 1.76 ± 0.10 mm, 5.04 ± 0.34

mm and 9.56 ± 0.17 mm. The average width of first, second and third larvae was 0.33 ± 0.04 mm, 1.09 ± 0.05 mm and 1.76 ± 0.06 mm. The duration for each instar was 1.92 ± 0.17 days, 2.5 ± 0.18 days and 3.75 ± 0.06 days. The total larval period had a range of 5 to 7.5 days, with an average duration of approximately 6.2 ± 0.28 days.

The larva, when fully developed, ceased its feeding activity, experienced a reduction in mobility. The pupa of *Bactrocera zonata* were cylindrical, segmented and initially appeared deep brownish-yellow and later on transformed into a dark reddish-brown. The average length was 4.56 ± 0.10 mm and width was 2.30 ± 0.05 mm. The average duration of pupal stage was 8.6 ± 0.38 days.

Adults are reddish-brown in colour with distinct yellow markings on their thorax. The size of female flies is larger than that of males. In case of adult male flies, the average length and width (wing expanse) was 7.37 ± 0.14 mm and 10.18 ± 0.09 mm whereas the average length and width of female flies was 7.80 ± 0.22 mm and 10.90 ± 0.18 mm. The male flies had a lifespan ranging from 15-24 days, with an average duration of 20.8 ± 0.98 days. The female flies had a lifespan ranging from 18-30 days, with an average duration of 26.3 ± 1.49 days. The pre-oviposition period, oviposition period, and post-oviposition period lasted for 11.3 ± 0.49 days, 6.00 ± 0.61 days and 4.5 ± 0.48 days, respectively.

5.3 Male Annihilation Techniques (MATs).

Out of the six treatments that were tested for fruit fly capture, treatment T₆ consists of methyl eugenol (4ml) + ethanol (6ml) + malathion (1ml) demonstrated notable superiority in comparison to the other treatments. Among the three species captured in the fruit fly traps, *Bactrocera dorsalis* had the highest population, followed by *Bactrocera zonata* and *Bactrocera scutellaris*.

5.4 Effectiveness of insecticides/botanicals against fruit fly.

Among all the tested insecticides/botanicals against *Bactrocera spp.*, chlorantraniliprole (0.005%), spinosad (0.004%), and cyantraniliprole (0.002%), demonstrated their effectiveness in controlling *Bactrocera spp.*, resulting in infestation rates of 12.50%, 15.00% and 16.67% respectively. Among the botanicals NSKE was more superior than agniastra.

5.5 Effectiveness of different bait formulations.

In the assessment of various baits for fruit fly control, bait 1 (Casein + Sugar + Banana pulp (1:1:1) + 5% ammonium acetate) was significantly more effective than other baits followed by bait 5 (Yeast + sugar + banana pulp (1:1:1) + 5% ammonium acetate). The female fruit fly population predominated over the male population.

CONCLUSION

The current investigation has provided valuable insights into the fruit fly population spanning from April 2022 to May 2023. It was observed that the highest fruit fly population occurred in the month of May 2023, followed by August 2022 and September 2022. The biological investigation revealed that the developmental period from immaturity to adulthood in females spanned from 18-30 days, with an average duration of 26.3 ± 1.49 days. For males, this period ranged from 15-24 days, with an average of 20.8 ± 0.98 days. Among the various Male Annihilation Techniques assessed for controlling fruit flies, the combination of methyl eugenol (4ml), ethanol (6ml), and malathion (1ml), using a septum measuring 8 cm × 2 cm × 1.8 cm, stood out as significantly more effective than other treatments. Among the different baits, the combination of casein, sugar, banana pulp (1:1:1) and 5% ammonium acetate proved significantly superior. In the evaluation of numerous insecticides and botanical treatments for their effectiveness, it was determined that chlorantraniliprole (0.005%), spinosad (0.004%) and cyantraniliprole (0.002%), exhibited notable efficacy in the control and management of fruit flies on peach trees.



Literature cited

LITERATURE CITED

- Abu-Ragheef AH and Al-Jassany RF. 2018. Study some biological aspects of peach fruit fly *Bactrocera zonata* (Saunders) (Diptera: Tephritidae): in laboratory and field study. *Journal of Agriculture, Biology and Healthcare*.8(12):67-74.
- Afia YE. 2007. Comparative studies on the biology and ecology of the two fruit flies, in Egypt *Bactrocera zonata* (Saunders) and *Ceratitis capitata* (Wiedemann). Ph. D. Thesis, Faculty of Agriculture, Cairo University. P301.
- Afzal M and Javed H. 2001. Evaluation of soaked wooden killer blocks for male annihilation (MA) on fruit fly *Bactrocera spp.* (Diptera: Tephritidae). *Journal of Biological Sciences*.1(7):577-579.
- Agarwal ML, Kumar P and Kumar V. 1999. Population suppression of *Bactrocera dorsalis* (Hendel) by *Bactrocera zonata* (Saunders) (Diptera: Tephritidae) in North Bihar. *Shashpa*.6:189–91.
- Anjum S, Razag M and Yazadni MS. 2000. Studies on seasonal activity and control of fruit flies (*Dacus spp.*) on mango (*Mangifera indica* L.) at Faisalabad, Pakistan. *Arab Journal of Plant Protection*.18(2):121–123.
- Anonymous. 2021. Horticulture AT A Glance. <http://nhb.gov.in>.
- Ashoka KS and Javaregowda. 2019. Comparative biology of fruit fly, *Bactrocera dorsalis* (Hendel) on mango genotypes. *International Journal of Current Microbiology and Applied Sciences*.8(11):2482-2486.
- Bana JK, Sharma H, Kumar S and Singh P. 2017. Impact of weather parameters on population dynamics of oriental fruit fly, *Bactrocera dorsalis* (Hendel) (Diptera: Tephritidae) under south Gujarat mango ecosystem. *Journal of Agrometeorology*. 19(1):78-80.
- Begam NS, Jalaluddin SM, Sithanantham S, Shanthi M, Thiruvudainambi S and Beaulah A. 2021. Population dynamics and seasonal incidence of two Tephritid fruit fly species in mango ecosystem under off-season fruiting in Tamil Nadu. *The Pharma Innovation*

Journal.10(2):126-130.

Bhatia SK and Mahto Y. 1969. Influence of temperature on the speed of development of melon fly (Diptera). *Indian Journal of Agricultural Sciences*.40(9):821-828.

Bhowmik P, Mandal D and Chatterjee ML. 2014. Chemical management of melon fruit fly, *Bactrocera cucurbitae* Coquillett (Diptera: Tephritidae) on bottle gourd. *Pesticide Research Journal*.26:68-73.

Chandaragi M, Sugandhi R, Kumar VMM and Uppar V. 2012. Evaluation of different trap designs for capture of fruit flies in mango orchard. p.28. In: Abstracts. International Conference on Entomology. Feb 17–19, 2012. Punjab University, Patiala.

Choudhary JS, Dhakar MK, Mukherjee D, Moanaro, Das B, Singh AK and Bhatt BP. 2018. Influence of some fruit traits of mango, *Mangifera indica* L. varieties against maggot development and infestation of mango fruit fly, *Bactrocera dorsalis* (Hendel). *Journal of Entomology and Zoology Studies*.6(2):2621–2627.

Choudhary JS, Kumari A, Das B, Maurya S and Kumar S. 2012. Diversity and population dynamic of fruit flies species in methyl eugenol-based para pheromone traps in Jharkhand region of India. *The Ecoscan*.1:57–60.

Christenson LE and Foote RE. 1960. Biology of fruit flies. *Annual Review of Entomology*.5:171-192.

Chu YI and Chen GJ. 1985. Behaviour of pupation and emergence in oriental fruit fly, *Dacus dorsalis* Hendel. *Pl Prot Bull Taiwan*.27:135-43.

Clarke AR, Powell KS, Weldon C and Taylor PW. 2011. The ecology of *Bactrocera tryoni* (Diptera: Tephritidae): what do we know to assist pest management. *Annals of Applied Biology*.158:26–54.

Dale NS. 2002. Studies on biology of *Bactrocera zonata* (Saunders) and management of fruit flies in mango orchards. M.Sc. Thesis. Gujarat Agricultural University, Gujarat.

Deepa M, Agarwal N, Viswakarma R, Kumari K and Lal KM. 2009. Monitoring and weather parameters on *Bactrocera* complex through methyl eugenol traps. *Annals of Plant Protection*

Sciences.17(2):332–336.

Draz KA, Tabikha RM, El-Aw MA, El-Gendy IR and Darwish HF. 2016. Population activity of peach fruit fly, *Bactrocera zonata* (Saunders) (Diptera: Tephritidae) at fruits orchards in Kafer El-Shikh Governorate, Egypt. *Arthropods*.5(1):28–43.

Dubale MM, Jalgaonkar VN, Naik KV and Golvankar GM. 2018. Evaluation of insecticides in the management of fruit flies infesting ridge gourd. *International Journal of Chemical Studies*.6(5):2428-2432.

Duyck PF, Sterling JF and Quilici S. 2004. Survival and development of different stages of *Bactrocera zonata* (Diptera: Tephritidae) reared at five constant temperatures compared to other fruit fly species. *Bulletin of Entomological Research*. 94:89-93.

Ekesi S and Mohamed SA. 2011. Mass rearing and quality control parameters for tephritid fruit flies of economic importance in Africa. pp 387–410. In: Isin, A. (ed.) *Wide Spectra of Quality Control*. InTech Publisher.

Ekesi S, Meyer MD, Mohamed SA, Virgilio M and Borgemeister C. 2016. Taxonomy, ecology, and management of native and exotic fruit fly species in Africa. *Annual review of Entomology*.61:219-38.

El-Gendy IR. 2018. Insecticide resistance of a field strain of Mediterranean fruit fly, *Ceratitis capitata* (Wiedemann) in Egypt. *Journal of Applied Sciences*. 18:25–32. <https://doi.org/10.3923/jas.2018.25.32>.

Fletcher BS. 1987. Temperature development rate relationships of the immature stages and adult of tephritid fruit flies. Robinson, A.S. and G. Hooper (Eds.) *Fruit Flies: their biology, natural enemies and control*. Elsevier World Crop Pests 3A, Amsterdam. p. 273- 289.

Foote D and Carey JR. 1987. Comparative demography of a laboratory and a wild strain of the oriental fruit fly, *Dacus dorsalis*. *Entomologia Experimentalis et Applicata*.44: 263-68.

Ghanim NM. 2009. Studies on the peach fruit fly, *Bactrocera zonata* (Saunders) (Tephritidae, Diptera). Ph. D. Thesis. Faculty of Agriculture, Mansoura University, Egypt. 121 p.

Ghanim NM. 2013. Influence of methyl eugenol diluted with paraffin oil on male annihilation

- technique of peach fruit fly, *Bactrocera zonata* (Saunders) (Diptera: Tephritidae). *Entomology, Ornithology & Herpetology*.2(3): 114.
- Gomez KA and Gomez AA. 1986. *Statistical procedure for agricultural research*, 2nd edition, John Willey and Sons, New York, U.K. 80p.
- Gupta D, Verma AK and Bhalla OP. 1990. Population of fruit-flies (*Dacus zonatus* and *Dacus dorsalis*) infesting fruit crops in north-western Himalayan region. *Indian Journal of Agricultural Sciences*.60(7):471-474.
- Hancock J and Scorza R. 2008. Peach. In: Temperate Tree Fruit Breeding. (Hancock J ed). New York, Springer. pp. 65-298.
- Hendrichs J, Teresa MV, Meye MD and Clarke AR. 2015. Resolving cryptic species complexes of major tephritid pests. *Zookeys*.540:5–39.
- Hosni M, EL-Husseini MM, EL-Heneidy and Atallah FA. 2011. Morphological and some biological aspects of the peach fruit fly, *Bactrocera zonata* (Saunders) (Diptera: Tephritidae). *Egyptian Journal of Agriculture Research*.91(2):449.
- Hussain A, Sajjad A, Salim J and Safiullah. 2010. Efficacy of different control methods against oriental fruit fly *Bactrocera zonata* (Saunders). *Journal of Agricultural and Biological Science*.5:1-3.
- Islam M, Latif MA, Ali M and Yeasmin S. 2013. Effect of different traps on the incidence and management of cucurbit fruit fly, *Bactrocera cucurbitae*. *Bangladesh Journal of Entomology*.23:51-64.
- Jalaluddin SM, Natarajan K, Sadakathulla S and Balasubramaniyam S. 1999. Discovery of the guava fruit fly, *Bactrocera correcta* (Bezzi). *Entomol.24(2):195–196*.
- Janjua NA. 1948. The biology of *Dacus ferrugineus* (Fab) (Diptera) in Baluchistan. *Indian Journal of Entomology*.10:55-61.
- Jayanthi PDK and Verghese A. 2002. A simple and cost-effective mass rearing technique for the tephritid fruit fly *Bactrocera dorsalis* (Hendel). *Current Science*.82(3):266- 268.
- Kabbashi EBM. 2014. Fruit insect pests of guava (*Psidium guajava* L.) and mango (*Mangifera*

- indica* L.) and their management in Sudan: a historic review. *Food Science & Technology Journal*.1(3):1-11.
- Kakar MQ, Ullah F, Saljoqi AUR, Ahmad S and Ali I. 2014. Determination of fruit flies (Diptera: tephritidae) infestation in guava, peach and bitter gourd orchards in Khyber Pakhtunkhwa. *Sarhad Journal of Agriculture*.30(2):241–246.
- Kalia VK and Yadav B. 2015. Cost-effective mass rearing of the oriental fruit fly, *Bactrocera dorsalis* (Hendel) round the year. *International Research Journal of Natural and Applied Sciences*.2(6):143-155
- Khalil AA, Abolmaaty SM, Hassanein MK, El-Mtewally MM, Moustafa SA. 2010. Degree-days units and expected generation numbers of peach fruit fly, *Bactrocera zonata* (Saunders) (Diptera: Tephritidae) under climate change in Egypt. *Egyptian Academic Journal of Biological Sciences*.3:11–19.
- Khan L, Haq M, Inayatullah C and Mohsan A. 1993. Biology and behaviour of melon fruit fly, *Dacus cucurbitae* Coquillet. (Diptera: Tephritidae). *Pakistan Journal of Zoology*.25(3):203-208.
- Khan MA, Ashfaq M and Khaliq A. 2003. Population of fruit fly species trapped by methyl eugenol and cue lure versus infestation in guava orchards. *Pakistan Entomologist*.25(1):63-67.
- Khan MH, Khuhro NH, Awais M, Asif MU and Muhammad R. 2021. Seasonal abundance of fruit fly, *Bactrocera species* (Diptera: Tephritidae) with respect to environmental factors in guava and mango orchards. *Pakistan Journal of Agricultural Research*.34(1):266-272.
- Khan MH, Khuhro NH, Awais M, Memon RM and Asif MU. 2020. Functional response of the pupal parasitoid, *Dirhinus giffardii* towards two fruit fly species, *Bactrocera zonata* and *Bactrocera cucurbitae*. *Entomologia Generalis*.40(1):87–95.
- Khan RA and Naveed M. 2017. Occurrence and seasonal abundance of fruit fly, *Bactrocera zonata* Saunders (Diptera: Tephritidae) in relation to meteorological factors. *Pakistan journal Zool*.49(3):999-1003.
- Khan S, Hussain S, Maula F, Khan M A, and Shinwari I. 2015. Efficacy of different lures in male

- annihilation technique of peach fruit fly, *Bactrocera zonata* (Diptera: Tephritidae). *Journal of Entomology and Zoology Studies*.3:164–168.
- Khattak MK, Jaffery AA, Hussain AS and Abdullah K. 2012. Bionomics and management studies of *Bactrocera zonata* (Saunders) (Diptera: Tephritidae). *Pakistan Entomologist*.34(1):65-69.
- Khatun N, Howlader MTH and Das G. 2015. Efficacy of abamectin alone or in combination with emamectin benzoate, lambda-cyhalothrin and lufenuron against the infestation of cucurbit fruit fly, *Bactrocera cucurbitae* (Coq.) *Journal of Entomology and Zoology Studies*.3(5):311-315.
- Khursheed S, Raj D. 2012. Bio-efficacy of certain insecticides and bio-pesticides against melon fruit flies, *Bactrocera spp.* *Pest Management in Horticultural Ecosystems*.18:143-148.
- Kumar B and Agarwal ML. 2004. Efficacy of different attractant and bait combinations against *Bactrocera cucurbitae* (Coquillett). *Indian Journal of Plant Protection*.33:194-196.
- Kumar R. 2005. Studies on fruit flies in guava and mango orchards with special reference to their management through mass trapping. M.Sc. Thesis. University of Agricultural Sciences, Dharwad. 90p.
- Kumar U, Prasad CS, Vaibhav V and Saran S. 2018. Population dynamics of mango fruit fly species caught through methyl eugenol traps at different locations of Western plain zone of Uttar Pradesh. *Journal of Pharmacognosy and Phytochemistry*.7(2):2167–2168.
- Kumar V and Agarwal ML. 1998. Efficacies of different bait combinations against oriental fruit fly, *Bactrocera dorsalis* (Hendel). *Journal of Research Birsa Agricultural University*. 10:83-86.
- Kunden A, Imrak B and Rehber Y. 2004. Peach, nectarine and plum growing possibilities under subtropical conditions of Turkey and North Cyprus. *Acta Horticulturae*.662:119- 21.
- Lanjar AG, Sahito HA, Talpur MA and Channa MS. 2013. Biology and population of melon fly on musk melon and Indian squash. *International Journal of Farming and Allied Sciences*.2(2):42-47.
- Laskar N. 2013. Biology and biometrics of melon fruit fly, *Bactrocera cucurbitae* (Coq.) on bitter gourd, *Momordica charantia* L. and pumpkin, *Cucurbita pepo* L. *Current Biotica*.7:51-59.

- Latif A, Abdullah K, Shah GS and Hussain S. 2002. Comparative study on baits and dust formulation of insecticide against fruit flies (Diptera: Tephritidae) on melon (*Cucumis melo*) under semi-arid condition of Dera Ismail Khan. *Asian Journal of Plant Sciences*.1:554–555.
- Mahmood K and Mishkatullah. 2007. Population dynamics of three species of genus *Bactrocera* (Diptera: Tephritidae: Dacinae) in BARI, Chakwal (Punjab). *Pakistan Journal of Zoology*.39(2):123-126.
- Mahmood T, Hussain SI, Khokhar KM, Ahmad M and Hidayatullah. 2002. Studies on methyl eugenol as a sex attractant for fruit fly *Daucus zonatus* in relation to abiotic factors in peach orchard. *Asian J. Plant Sci*.4(1):401-402.
- Mahmoud MF and Shoaib MA. 2008. Sterilant and oviposition deterrent activity of neem formulation on peach fruit fly *Bactrocera zonata* (Saunders) (Diptera: Tephritidae). *Journal of Biopesticide*.1:177-181.
- Mahmoud YA. 2004. Studies on the peach fruit fly *Bactrocera zonata* (Saunders) with special reference to the effect of gamma-ray. Ph. D. Thesis. Menoufia University.
- Mann GS. 1990. Bioecology and management of fruit flies. Summer Institute of Key Pests of India, their bioecology with special reference to Integrated Pest Management. Department of Entomology, Punjab Agricultural University, Ludhiana. June 6-15, 1990: pp 236-57.
- Mann GS. 1996. Relative efficacy of some insecticides with or without protein hydrolysate bait against the oriental fruit fly infesting guava in Punjab. *Pest Management and Economic Zoology*.4:71-75.
- Manzar and Srivastava JP. 2009. Biology of melon fruit fly, *Bactrocera cucurbitae* (Coq.) on bitter gourd (*Momordica charantia* L.). *Trends in Biosciences*.2(1):42- 43.
- Mariadoss A, Samson DG, Teja V and Sujeetha RP. 2020. Species diversity of fruit flies in different varieties of mango in Ranga Reddy district of Telangana state, India. *Journal of Entomology and Zoology studies*.8(4):184-187.
- Mir SH, Dar SA, Mir GM and Ahmad SB. 2014. Biology of *Bactrocera cucurbitae* (Diptera: Tephritidae) on cucumber. *Florida Entomologist*.97(2):753-758.

- Mir SH, Mir GM, Dar SA and Haji SA. 2015. Biology and biometrics of the peach fruit fly, *Bactrocera zonata* on peach. *Indian Journal of Plant Protection*.43(2):154-157.
- Mosleh YY, Yousry LH, Abo-Elaa A. 2011. Toxicological and biochemical effects of some insecticides on peach fruit fly, *Bactrocera zonata* (Diptera: Tephritidae). *Plant Protection Science*.47:12.
- Murtaza G, Fazlullah, Ahmad T, Ramzan M, Daud M, Iqbal S, Ali A and Ramzan M. 2021. Biology and morphology of *Bactrocera dorsalis* and *Bactrocera zonata* on guava under laboratory conditions. *Indian Journal of Pure and Applied Biosciences*.9(4):180-185.
- Naik HS, Jagadeesh KS and Basavaraju BS. 2017. Biology and biometrics of oriental fruit fly, *Bactrocera dorsalis* (Hendel) (Diptera: Tephritidae) on Custard Apple, *Annona squamosa* L. *International Journal of Current Microbiology and Applied Sciences*.6(12):3859-3864.
- Nakahara S and Muraji M. 2008. Phylogenetic analyses of *Bactrocera* fruit flies (Diptera: Tephritidae) based on nucleotide sequences of the mitochondrial COI and COII genes. *Research Bulletin of the Plant Protection Service Japan*.44:1-12.
- Narayanan ES and Batra HN. 1960. Fruit flies and their Control. Indian Council of Agricultural Research, New Delhi. 68p.
- Nath P, Bushan S and Kumar A. 2007. Efficacy of certain ecofriendly insecticides and bait spray against fruit fly (*B. cucurbitae*) infesting fruits of bottle gourd. *Vegetable Science*.34:150-152.
- Ndiaye M, Dieng EO and Delhove G. 2008. Population dynamics and on-farm fruit fly integrated pest management in mango orchards in the natural area of Niayes in Senegal. *Pest Management in Horticultural Ecosystems*.14:1–8.
- Oke OA. 2008. Effectiveness of two insecticides to control melon fruit fly (*Bactrocera cucurbitae*) (Coquillet) in cucumber (*Cucumis sativus* L). crop at Anse Boileau Seychelles. *European Journal of Science and Research*.22(1):84-86.
- Pal S, Kumar S, Chandra S, Pati R and Singh DK. 2015. Fruit flies, *Bactrocera* spp. relationship between trap captures and weather parameters. *Annals of Biology*.31(1): 104–108.
- Pandey AK, Paras N, Rai A, Kumar A and Gupta S. 2010. Influence of poison baits and weather

- factors on fruit fly (*Bactrocera cucurbitae* Coq.) catches in cucurbits. *Vegetable Science*.37(1):67-68.
- Pant JC, Srivastava BG and Anand M. 1989. Role of pH in the diet of *Dacus dorsalis* (Hendel) maggots under aseptic conditions. *Indian J. Ent.* 51:408-11.
- Patel NA, Facknath S and Sookar P. 2023. Development of a waste brewery yeast larval diet for rearing *Bactrocera zonata* for use in SIT. *Phytoparasitica*.51:285-303.
- Patel RK, Verghese A, Patel VM, Joshi BK, Stonehouse JM and Mumford JD. 2005. Bait, lure and cultural IPM of fruit flies in mango in Gujarat. *Pest Management of Horticultural Ecosystem*.11:155-56.
- Patel ZP, Jhala RC, Jagadale VS, Sisodya DB, Stonehouse JM, Verghese A and Mumford JD. 2005. Effectiveness of woods for soaked-block annihilation of male fruit flies in Gujarat. *Pest Management in Horticultural Ecosystems*.11:117-20.
- Raghuvanshi AK, Satpathy S, Mishra DS. 2012. Role of abiotic factors on seasonal abundance and infestation of fruit fly, *Bactrocera cucurbitae* (coq.) on bitter gourd. *Journal of Plant Protection Research*.52(2):264-267.
- Rai S, Shankar U, Bhagat R M and Gupta S P. 2008. Population dynamics and succession of fruit fly on subtropical fruits under rained condition in Jammu region. *Indian Journal of Entomology*.70(1):12–15.
- Rajitha AR and Viraktamath S. 2005. Response of fruit flies to different types of traps in mango orchard. *Pest Management in Horticulture Ecosystem*.11:15-25.
- Rajitha AR and Viraktamath S. 2006. Monitoring of fruit flies (Diptera: Tephritidae) in guava orchard at Dharwad, Karnataka. *Journal of Agricultural Sciences*.19(1):45–49.
- Rajitha AR. 2004. Monitoring of fruit flies using different types of traps and lures in guava and mango. Ph. D. Thesis. Department of Agricultural Sciences, University of Agricultural Sciences GKVK, Bangalore.32-45p.
- Rana H, Khan MF, Eijaz S, Akbar MF, Achakazi JK, Khan MS, Hashmi SNA and Javed T. 2015. Effects of cypermethrin on fecundity, fertility, pupation, adult emergence and survival rate of

- melon fruit fly *Bactrocera cucurbitae* (COQ.). *International Journal of Biology and Biotechnology*.12(4):633-638.
- Rana HS and Sharma LK. 2012. Enhancement of temperate fruit production in changing climate. Department of pomology, Directorate of Research, University of Horticulture and Forestry, Solan (HP).399p.
- Rana JS, Prakash O and Verma SK. 1992. Biology of guava fruit fly infesting guava fruits in Haryana and influence of temperature and relative humidity on its incidence. *Journal of Crop Research*.5(3):525-529.
- Rana K and Kanwar HS. 2014. Evaluation of eco-friendly techniques for management of melon fruit flies (*Bactrocera spp.*) in bitter melon (*Momordica charantia* L.). *Pest Management in Horticultural Ecosystems*.20(1):100-102.
- Rattanapun W. 2009. Mango varietal preference and the effect of physiological changes during mango ripening on host utilization by *Bactrocera dorsalis* (Hendel) (Diptera: Tephritidae) [PhD thesis]. Bang Kok: Graduate School, Kasetsart University.137p.
- Rauf I, Ahmad N, Masoom SM, Rashdi S, Ismail M and Khan H. 2013. Laboratory studies on ovipositional preference of the peach fruit fly *Bactrocera zonata* (Saunders) (Diptera: Tephritidae) for different host fruits. *African Journal of Agricultural Research*.8(15):1300-1303.
- Ravikumar CH. 2005. Studies on fruit flies in guava and mango orchards with special reference to their management through mass trapping. M.Sc. (Agri.) Thesis, Uni. Agric. Sci., Dharwad (India).90p.
- Ravikumar P. 2006. Studies on fruit fly trapping systems using methyl eugenol and protein food baits in guava and mango orchards. M. Sc. Thesis, University of Agricultural Sciences, Dharwad (India).
- Rizk MMA, Abdel-Galil FA, Temerak SAH and Darwish DYA. 2014. Factors affecting the efficacy of trapping system to the peach fruit fly (PFF) males, *Bactrocera zonata* (Saunders) (Diptera: Tephritidae). *Archives of Phytopathology and Plant Protection*. 47(4):490–498. doi:10.1080/03235408.2013.813110.

- Rull J, Encarnacion N and Birke A. 2012. Mass rearing history and irradiation affect mating performance of the male fruit fly, *Anastrepha obliqua*. *Journal of Insect Science*.12:45.
- Saafan MH, Foda SM and Mohammed AA. 2006. Ecological studies on fruit flies on different hosts at Fayoum Governorate, Egypt. *Journal Agricultural research*.84(2): 323-336.
- Saafan MH. 2005. Field evaluation of some attractants for attracting the adults of Mediterranean fruit fly, *Ceratitidis capitata* Wied. And peach fruit fly, *Bactrocera zonata* Saunders in citrus orchards. *Egyptian Journal of Agriculture Research*.83:1141-56.
- Saeed M, Ahmad T, Alam M, Al-Shuraym LA, Nazeer AN, Alshehri MA, Ullah H and Sayed SM. 2022. Preference and performance of peach fruit fly (*Bactrocera Zonata*) and melon fruit fly (*Bactrocera Cucurbitae*) under laboratory conditions. *Journal of Biological Sciences*.29(4):2402–2408.
- Sapkota R, Dahal KC and Thapa RB. 2010. Damage assessment and management of cucurbit fruit flies in spring-summer squash. *Journal of Entomology and Nematology*.2:7-12.
- Sarada G, Maheswari TU and Purushotham K. 2001. Seasonal incidence and population fluctuation of fruit flies in mango and guava. *Indian Journal of Entomology*.63:272–276.
- Sarwar M, Hamed M, Yousaf M and Hussain M. 2014. Surveillance on population dynamics and fruits infestation of tephritid fruit flies (Diptera: Tephritidae) in mango (*Mangifera indica* L.) orchards of Faisalabad, Pakistan. *International journal of scientific research in environmental sciences*.2(4):113-119.
- Sawai HR, Godse SK, Narangalkar AL, Haldankar PM, Sanas AP. 2014. Bio efficacy of some insecticides against fruit flies infesting ridge gourd. *Journal of Soils and Crop Science*.24(1):174-180.
- Shankar M, Rao SRK, Umamaheswari T and Reddy KD. 2010. Effect of number and size of holes of trap on capturing efficiency of *Bactrocera spp.* in mango. *Annals of Plant Protection Sciences*.18:231-32.
- Sharma I. 2018. Fertility table studies on fruit flies [*Bactrocera dorsalis* (Hendel) and *B. zonata* (Saunders)] on different fruit hosts and their management. Ph. D. Thesis. Department of

Entomology. Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan. p 112.

Sharma K, Sharma RK, Chander S and Jilu V. 2015. Effects of weather parameters on guava fruit fly (*Bactrocera zonata*) population at IARI, New Delhi. *Journal of Agrometeorology*.17(2):227-229.

Sharma K. 2012. Fruit fly management at Indian Agricultural Research Institute for production of organic fruits with male annihilation technique. International Conference on Entomology. P. 82.

Sharma KS, Punam and Kumar R. 2016. Management of fruit fly (*Bactrocera spp.*) in cucumber (*Cucumis sativus* Linn.) grown organically. *Journal of Biopesticide*.5:1-6.

Sharma RK and Sinha SR. 2009. Evaluation of some novel and eco-friendly insecticides against fruit fly of bitter gourd. *Journal of Insect Science*.22(2):202-203.

Shehata NF, Younes MWF and Mahmoud YA. 2008. Biological studies on the peach fruit fly, *Bactrocera zonata* (Saunders) in Egypt. *Journal of Applied Sciences Research*. 4:1103-1106.

Shivangi L and Swami H. 2017. Bio-intensive management of fruit fly, *Bactrocera cucurbitae* (Coquillett.) in cucumber. *Journal of Entomology and Zoology Studies*.5(3):1823-1826.

Shivayya V, Kumar CT and Chakravarthy AK. 2007. Biology of melon fly, *Bactrocera cucurbitae* on different food sources. *Indian Journal of Plant Protection*.35:25-28.

Shukla RP, Verghese A, Singh HS, Patel RK, Faleiro R, Jiji T, Thomas J, Manzar A, Mohantha A, Joshi BK, Mumford JD and Stonehouse JM. 2005. The effects of substrate and dose on the catch and persistence of male annihilation killing points for fruit fly control. *Pest Management of Horticultural Ecosystems*.11(2):138-139.

Singh HS, Verghese A, Stonehouse JM, Mumford JD, George S, Naik G and Panday V. 2008. Developing bait and lure based integrated pest management module for mango fruit fly (*Bactrocera dorsalis*) management in Orissa. *Indian Journal of Agriculture Science*.78:609-613.

Singh M, Sharma KC, Bhardwaj RK and Sharma PL. 2017. Mass trapping of fruit flies (*Bactrocera spp.*) in cucumber using Para pheromone in Himachal Pradesh. *Indian Journal of*

Entomology.79:274-77.

Singh P and Mann GS. 2003. Population studies of fruit fly, *Bactrocera dorsalis* (Hendel) on peach. *Journal of Insect Sciences*.16:24–28.

Singh S and Sharma DR. 2011. Comparison of the trapping efficacy of different types of methyl eugenol-based traps against fruit flies, *Bactrocera spp.* infesting kinnow mandarin in the Indian Punjab. *Journal of Insect Science*.24:109–114.

Sood N and Sharma DC. 2004. Bio-efficacy and persistent toxicity of different insecticides and neem derivatives against cucurbits fruit fly, *Bactrocera cucurbitae* (Coquillett) on summer squash. *Pesticide Research Journal*.16:22-25.

Stanley J, Gupta JP and Rai D. 2015. Population dynamics of fruit flies, *Bactrocera spp.* in Northwestern Himalaya. *Indian Journal of Entomology*.77(3):214–220. doi: 10.5958/0974-8172.2015.00045.0.

Stonehouse JM, Afjal M, Zia Q, Mumford JD, Poswal A and Mahmood R. 2002. “Single- killing point” field assessment of bait and lure control of fruit flies (Diptera: Tephritidae) in Pakistan. *Crop Protection*.21:651-59.

Stonehouse JM, Mahmood R, Poswal A, Mumford J, Baloch KN, Chaudhary ZM, Makhdum AH, Mustafa G and Huggett D. 2002. Farm field assessments of fruit flies (Diptera: Tephritidae) in Pakistan: distribution, damage and control. *Crop Protection*.8(21):661–669.

Stonehouse JM, Mumford JD, Verghese A, Shukla RP, Satpathy S, Singh HS, Jiji T, Thomas J, Patel ZP, Jhala RC, Patel RK, Manzar A, Shivalingaswamy TM, Mohanta AK, Nair B, Vidya CV, Jagadale VS, Sisodiya DB and Joshi BK. 2007. Village level area wide fruit fly suppression in India: Bait application and male annihilation at village level and farm level. *Crop Protection*.26:788-93.

Tan KH, Nishida R, Jang EB and Shelly TE. 2014. Pheromones, male lures and trapping of tephritid fruit flies. *Trapping and the detection, control and regulation of tephritid fruit flies*.15-74.

Thakur M. 2011. Population monitoring and management of fruit flies *Bactrocera spp.* infesting

- vegetable and fruit crops. Ph.D. Thesis. Department of Entomology, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan. 160p.
- Urbaneja A, Chueca P, Monton H, Sara PR, Dembilio O, Vanaclocha P, Raquel AM, Pina T and Pedro C. 2009. Chemical alternatives to malathion for controlling *Ceratitidis capitata* (Diptera: Tephritidae), and their side effects on natural enemies in Spanish citrus orchards. *Journal of Economic Entomology*.102:144-51.
- Vargas RI, Mau RFL, Stark JD, Pinero JC, Leblanc L and Souder SK. 2010. Evaluation of methyl eugenol and cue-lure traps with solid lure and insecticide dispensers for fruit fly monitoring and male annihilation in the Hawaii area wide pest management program. *Journal of Economic Entomology*.103:409-15.
- Vargas RI, Pinero JC, Mau RFL, Stark JD, Hertlein M and Mafra-Neto A. 2009. Attraction and mortality of oriental fruit flies to SPLAT-MAT-methyl eugenol with spinosad. *Entomologia Experimentalis et Applicata*.131:286-93.
- Vargas RI, Walsh WA, Jang EB, Armstrong JW and Kanehisa DT. 1996. Survival and development of immature stages of four Hawaiian fruit flies (Diptera: Tephritidae) reared at five constant temperatures. *Ann ent Soc Am*.89:64-69.
- Vasudha A, Ahmad MA and Agarwal ML. 2019. Life history traits and immature stages of *Zeugodacus tau* (Walker) (Diptera: Tephritidae). *Journal of Entomology and Zoology studies*.7(2):1149-1153.
- Verma JS and Nath A. 2006. Management of fruit flies through trapping-a review. *Agric Rev*. 27:44-52.
- Verma VD, Pradheep K, Yadav SK, Rana JC and Chander R. 2009. Evaluation of indigenous and exotic peach germplasm under upper hill conditions. *Indian Journal of Horticulture*.66:415-419.
- Vinutha B and Kotikal YK. 2018. Management practices for fruit fly, *Bactrocera cucurbitae* Coq. affected on *Cucumis melo* L. *Journal of Entomology and Zoology Studies*.6(3):99-100.
- Wang B, Huang JC, Ji-Qing E, Yang JQ and Chen JH. 2010. A study on the production of protein

- bait for *Bactrocera dorsalis* (Hendel). *Acta Agriculturae Universitatis Jiangxiensis*.32:299-302.
- Waseem MA, Naganagoud A, Sagar D and Kareem MA. 2012. Biology of melon fly, *Bactrocera cucurbitae* (Coquillett) on cucumber. *BIOINFOLET-A Quarterly Journal of Life Sciences*.9(2):232-239.
- Waseem MA, Patil BV, Prabhuraj A and Hussain A. 2009. Efficacy of some insecticides against melon fly, *Bactrocera cucurbitae* Coquillett on cucumber. *Journal of Agricultural Sciences*.22(30):701-702.
- Wazir ZA, Singh AK and Ramana N. 2019. Seasonal incidence of fruit fly on summer squash (*Cucurbita pepo* L.) and effect of weather parameters on population dynamics of fruit fly *Bactrocera cucurbitae* (Coquillett). *Journal of Entomology and Zoology Studies*.7(5):167–170.
- White IM and Elson-Harris M. 1994. Fruit flies of economic significance: Their Identification and Bionomics. CAB International, Wallingford, Oxon, UK. 601 pp.
- Zhao JP, Tian SY, Liang GQ, Liang F and Wu JJ. 2004. The toxicity of several insecticides to the pupas of *Bactrocera dorsalis*. *Acta Agriculturae Universitatis Jiangxiensis*.26(2):286-288.



Appendix

APPENDIX

Analysis of Variance Table 4.1.

Seasonal abundance of fruit fly species that affect fruit crops in Neri, Hamirpur, across various months in the period spanning (2022 to 2023)

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	55,368.792			
Treatment	13	215,448.812	16,572.986	16.866	0.00000
Error	26	25,548.120	982.620		
Total	41	296,365.724			

Analysis of Variance Table 4.3.

Correlation study of fruit fly incidence with weather parameters

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Regression	4	54,444.835	13,611.209	7.053	0.00742
Error	9	17,368.603	1,929.845		
Total	13	71,813.440			

Analysis of Variance Table 4.5.

Morphometrics (length) of different life stages of *Bactrocera zonata* Saunders

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Treatment	6	591.757	98.626	289.954	0.00000
Error	63	21.429	0.340		
Total	69	613.187			

Analysis of Variance Table 4.5.

Morphometrics (width) of different life stages of *Bactrocera zonata* Saunders

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Treatment	6	1,300.636	216.773	2,779.207	0.00000
Error	63	4.914	0.078		
Total	69	1,305.550			

Analysis of Variance Table 4.6.

Duration of different life stages of *Bactrocera zonata* Saunders

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Treatment	9	9,202.030	1,022.448	130.218	0.00000
Error	90	706.662	7.852		
Total	99	9,908.692			

Analysis of Variance Table 4.7.

Evaluation of different Male Annihilation Techniques (MATs) during April 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	2.861			
Factor A	5	108,707.236	21,741.447	23,394.753	0.00000
Factor B	2	22,224.424	11,112.212	11,957.228	0.00000
Interaction A X B	10	10,580.465	1,058.047	1,138.505	0.00000
Error	34	31.597	0.929		
Total	53	141,546.583			

Analysis of Variance Table 4.8.

Evaluation of different Male Annihilation Techniques (MATs) during May 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	2.155			
Factor A	5	140,940.228	28,188.046	54,990.837	0.00000
Factor B	2	44,738.086	22,369.043	43,638.797	0.00000
Interaction A X B	10	28,292.248	2,829.225	5,519.412	0.00000
Error	34	17.428	0.513		
Total	53	213,990.145			

Analysis of Variance Table 4.9.

Evaluation of different Male Annihilation Techniques (MATs) during June 2023

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	0.225			
Factor A	5	31,132.061	6,226.412	10,334.902	0.00000
Factor B	2	3,113.502	1,556.751	2,583.971	0.00000
Interaction A X B	10	440.512	44.051	73.118	0.00000
Error	34	20.484	0.602		
Total	53	34,706.784			

Analysis of Variance Table 4.10.

Efficacy of different insecticides/botanicals against different species of fruit fly

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	1	4.956			
Treatment	6	84.780	14.130	416.237	0.00000
Error	6	0.204	0.034		
Total	13	89.940			

Analysis of Variance Table 4.11.

Evaluation of various baits for capturing female fruit flies during different months at Neri

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	16.028			
Factor A	2	103.444	51.722	8.751	0.00026
Factor B	3	667.870	222.623	37.665	0.00000
Int A X B	6	284.296	47.383	8.017	0.00000
Factor C	5	510.333	102.067	17.268	0.00000
Int A X C	10	12.056	1.206	0.204	0.99567
Int B X C	15	320.296	21.353	3.613	0.00003
Int A X B X C	30	600.870	20.029	3.389	0.00000
Error	142	839.306	5.911		
Total	215	3,354.500			

Analysis of Variance Table 4.12.

Evaluation of various baits for capturing male fruit flies during different months at Neri

Source of Variation	DF	Sum of Squares	Mean Squares	F-Calculated	Significance
Replication	2	22.583			
Factor A	2	84.194	42.097	7.722	0.00066
Factor B	3	296.037	98.679	18.102	0.00000
Int A X B	6	127.324	21.221	3.893	0.00125
Factor C	5	609.222	121.844	22.351	0.00000
Int A X C	10	12.250	1.225	0.225	0.99357
Int B X C	15	185.185	12.346	2.265	0.00682
Int A X B X C	30	444.454	14.815	2.718	0.00004
Error	142	774.083	5.451		
Total	215	2,555.333			

Abstract



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No. of pages in Thesis	:	70+ iv
No. of words in Abstract	:	212
Date of Thesis Submission	:	

ABSTRACT

The present investigations on “Seasonal incidence, biology and management of peach fruit fly under low hills conditions of Himachal Pradesh” were conducted during 2022-2023. The investigation has provided valuable insights into the fruit fly population spanning from April 2022 to May 2023. It was observed that the highest population of fruit flies occurred in the month of May 2023, followed by August 2022 and September 2022. The biological investigation revealed that the developmental period from immaturity to adulthood in females spanned from 18-30 days, with an average duration of 26.3 ± 1.49 days. For males, this period ranged from 15-24 days, with an average of 20.8 ± 0.98 days. Among the various Male Annihilation Techniques assessed for controlling fruit flies, the combination of methyl eugenol (4ml), ethanol (6ml), and malathion (1ml), using a septum measuring 8 cm × 2 cm × 1.8 cm, stood out as significantly more effective than other treatments. Among different baits experimented to combat fruit flies, the combination of casein, sugar, banana pulp (1:1:1) and 5% ammonium acetate proved significantly superior. In the evaluation of numerous insecticides and botanical treatments for their effectiveness, it was determined that chlorantraniliprole (0.005%), spinosad (0.004%) and cyantraniliprole (0.002%), exhibited notable efficacy in the control and management of fruit flies on peach trees.

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Whether sponsored by some state/ Central Govt./ Univ./ SAARC : NO

Scholarship/ Stipend/ Fellowship, any other financial assistance received during the study period : YES

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