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Research Article

Biology, Seasonal Incidence and Evaluation of Various Male Annihilation Techniques (MATs) for Catches of *Bactrocera dorsalis* Infesting Guava in Lower Hills of Himachal Pradesh

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Abstract

The objective of the study was to record data on biology, seasonal fluctuations and evaluation of various male annihilation techniques for *Bactrocera dorsalis* on Guava in Himachal Pradesh. In seasonal fluctuation, the population was at its apex in the month of September followed by August and July. The fruit fly passes through egg, 3 larval instars, pupal and adult stage. Maggot period was around 8 days. The biological study evidenced that developmental period from immature to adult females varied from 19 to 29 days and that of males ranged between 16 to 22 days and averaged for 18.70 ± 0.62 days. Out of different Male Annihilation Techniques evaluated against fruit fly, Methyl Eugenol (4ml) + Ethanol (6ml) + Malathion (1ml) with septum size (8 × 2 × 1.8 cm3), was notably superior to other treatments. Among the three species captured in fruit fly traps, the population of *B. dorsalis* was maximum, followed by *B. zonata* and *B. scuttelaris*.

Keywords: Biology; Seasonal Incidence; *Bactrocera dorsalis*; Male Annihilation Techniques (MATs)

Introduction

Fruit flies (family Tephritidae) are a serious hazard to global fresh fruit and vegetable exports as well as fruit and vegetable production. Because of widespread distribution, invasive ability, pest status, and economic losses to fruit and vegetable crops, this insect species is considered as a pest warranting severe quarantine restrictions by many countries in the world [1]. Its rapid growth rate enables it to be a multi-voltine pest with 8-9 generations per year [2]. A majority of fruit and vegetables have been recorded as its hosts which include guava, peach, mango, tomato and many cucurbits [3-4]. Both the quality and quantity of fruits deteriorate as infested fruits rot and drop. The consumers are also scared to buy and eat infested fruits, as the maggots present inside make them feel irritated. Fruit flies severely and severely damage two significant fruit crops: guava and mango. *Bactrocera dorsalis* Hendel, *B. zonata* (Saunders), and *B. correcta* Bezzi are the most prevalent and dominant species that attack on these two fruits [5-6]. These fruit flies are responsible for a great deal of damage and devastation to fruits and vegetables throughout the Indo-Pak peninsula [7]. *B. dorsalis* can cause fruit damage to mango and guava that ranges from 87.0 percent to 100.0 percent during the rainy season [8]. For protecting agricultural products, human health and the environment from misused pesticides, the governments of many countries plan large budgets to carry out integrated pest management (IPM) programs in order to provide practical ways to reduce its infestation by reducing the use of toxic pesticides, while preserving the productivity of the farms. Continuous monitoring of maggots and adults of pest population are essential to assess the prerequisites and successfulness of any control programme.

The most effective and widely used way of controlling fruit flies is the employment of male lures, often known as the Male Annihilation Technique [9-10]. The male annihilation technique (MAT) is a fruit fly control strategy that kills and reduces the likelihood of mating. Thus, females produce very few offspring. As a result, the wild population in the target area declines, which eventually leads to elimination. It is an essential part of integrated pest management strategies for controlling fruit flies and sterile insect techniques [11-12]. Different classes of male attractants strongly entice male Tephritidae fruit flies, yet the mechanism of attraction and detection remain unclear. For example, males of *B. dorsalis* and *B. zonata* are highly capitavated to methyl eugenol, while *B. cucurbitae*

and *B. tryoni* are allured to cuelure and *C. capitata* and some other *Ceratitis* spp. are dazzaled to trimedlure [13]. Large orchards can be protected from fruit fly incursions by placing traps of various sizes along their perimeter. This method not only yields encouraging results but is also environmentally friendly [14]. Toxic baits are regarded as a pest management strategy to reduce the number of fruit flies without dispersing insecticide [15]. The basis of the male annihilation approach is methyl eugenol combined with an insecticide that has been put into a suitable substrate. The current study was conducted to understand the biology, seasonal incidence and to assess various male annihilation approaches for the management of *B. dorsalis* on guava in Himachal Pradesh, keeping in mind the significance of fruit harvests.

Materials and Methods

The current research was conducted in the Department of Entomology at the College of Horticulture and Forestry in Neri (Hamirpur), Himachal Pradesh. The department is located at an altitude of 650 meters above mean sea level and at longitudes 31° 41' N and latitudes 72° 28' E.

Biology of *B. dorsalis* infesting guava in low hills of Himachal Pradesh

Stock culture: Infested guava fruits were collected from experimental area of the Neri farm after regular visits for infested fruits and kept in rearing cages for further studies. Pupae were collected and placed in separate cages. Freshly emerged male and female fruit fly adults, were then confined to semisolid diet of protein hydrolysate kept in plastic petri dishes which were placed in the rearing cages. For adult feeding, a sponge dipped in 5 percent honey solution was placed in the rearing cage. Adults of fruit fly after mating laid eggs in the fresh guava fruits inside the rearing cage. The fruits with freshly laid eggs were then used for the study of biology. For the shape, size and colour, 10 eggs in three replicates were examined under the microscope. Length and breadth of eggs was measured in mm using digital Vernier calliper and were observed twice a day for recording egg period. The larvae hatched were reared in petri dish (10 cm diameter) on fresh guava 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. The 3rd instar maggot suspended feeding, stopped movements and became sluggish before ecdysis to pupation and hops out of fruit.

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 × 4 cm). 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 observed daily, till adult emergence to ascertain the pupal period. On the presence or absence of ovipositor and their abdomen size, sexes of flies were determined. 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. Sex ratio means total number of male and female fruit flies emerged out from the same lot of pupae.

Seasonal abundance of fruit fly in the Low and Shivalik hills of Himachal Pradesh using MATs

The experiment was conducted for one calendar year from May, 2019 to April, 2020 to observe the seasonal abundance of fruit fly in different months of the year. Locally made bottle traps were installed at a distance of 50 m in guava orchard, at Neri Farm, Hamirpur (H.P.). For conducting this experiment plywood pieces (called as septa) of 8 × 2 × 1.8 cm^3 sizes were soaked in Methyl Eugenol (4ml) + Ethanol (6ml) + Malathion (1ml) solution and these septa were kept overnight for complete saturation. These septa were placed in locally made bottle traps. The trap was designed with four openings on each side to allow fruit flies to enter. The population of the fruit fly was recorded fortnightly w.e.f. May 2019 - April 2020 (Figure 1).

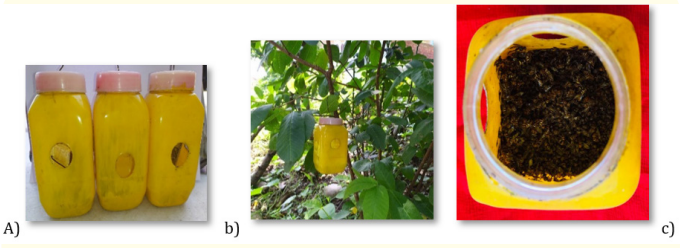


Figure 1: Traps used in monitoring for seasonal abundance a) traps used in monitoring; b) in field; c) Flies trapped.

Evaluation of various MATs for catches of fruit fly species

- **Installation of fruit fly traps:** The purpose of the binding wire was to keep the septa hanging close to the trap's lid and prevent them from falling to the trap's base, where rainwater

may lessen the effect of chemicals soaked in the septa. Traps were hung six feet above the experimental trees with the binding wire threaded through the lid.

- **Preparation of pheromones:** After being cleaned in hot water, the plywood pieces were allowed to air dry. After being immersed in various combinations of chemicals (Methyl Eugenol, Ethanol, Malathion, Cypermethrin, and Spinosad), the plywood pieces (8 × 2 × 1.8) and (4 × 2 × 1.8) cm^3 were left overnight to achieve total saturation (Table 1; Figure 2). These septa were placed in traps.

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

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

Statistical analysis

The data were tabulated and analysed using two-way analysis of variance was used for analyzing data of Male Annihilation Techniques treatments (Statistix 10 software) and the significance of various treatments was evaluated using Duncan Test. The values on fruit fly catches were subjected to square root transformation before analysis.

Treatment	Chemicals in Septa
T_1	Palam Trap
T_2	Methyl Eugenol (2ml) + Ethanol (3ml) +Malathion (0.5ml)
T_3	Methyl Eugenol (2ml) + Ethanol (3ml) + Cypermethrin (0.5ml)
T_4	Methyl Eugenol (2ml) + Ethanol (3ml) + Spinosad (0.5ml)
T_5	Methyl Eugenol (4ml) + Ethanol (6ml) + Cypermethrin (1ml)
T_6	Methyl Eugenol (4ml) + Ethanol (6ml) + Spinosad (1ml)
T_7	Methyl Eugenol (4ml) + Ethanol (6ml) + Malathion (1ml)

Table 1: Details of treatments used for evaluation of MAT's in management of *Bactrocera dorsalis*.

*Each Treatment was replicated thrice.

T_1: Was a standardized Palam Trap. Septa size used for treatments; T_2-T_4: Was 4 × 2 × 1.8 cm^3 and same for treatments; T_5-T_7: Was 8 × 2 × 1.8 cm^3. All the 7 treatments were replicated thrice under Randomized Block Design.

Results

Biology of fruit fly infesting guava in low hills of Himachal Pradesh

The study on the developmental biology was carried out for the fruit fly, *B. dorsalis* under laboratory conditions and data on the life history and biometrical studies were presented in tables 2 and 3.

Stages	Length (mm)		Width (mm)	
	Range	Mean ± SE**	Range	Mean ± SE**
Egg	0.85 - 2.10	1.30 ± 0.13	0.15 - 0.30	0.23 ± 0.01
1st Instar	1.30 - 3.60	2.81 ± 0.40	0.25 - 0.70	0.42 ± 0.04
2nd Instar	5.50 - 7.95	6.37 ± 0.25	0.82 - 1.34	1.03 ± 0.05
3rd Instar	7.70 - 9.2	8.28 ± 0.13	1.20 - 1.80	1.65 ± 0.07
Pupa	4.20 - 4.81	4.61 ± 0.06	1.85 - 2.20	2.04 ± 0.03
Adult*				
Male	6.39 - 8.21	7.57 ± 0.20	11.46 - 12.40	11.98 ± 0.09
Female	7.56 - 9.79	8.38 ± 0.20	12.14 - 13.13	12.77 ± 0.09

Table 2: Morphometry of different stages of *B. dorsalis*

*Width with expanded wings

**SE = Standard Error

Values are average of 10 observations in 3 replications.

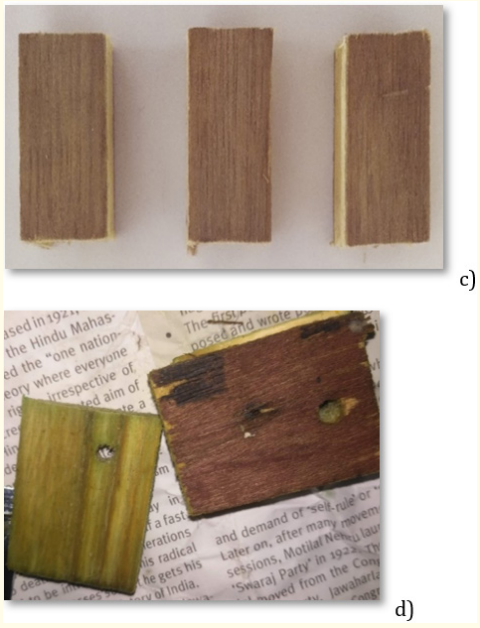
Stages	Range (Days)	Mean ± SE* (Days)
Incubation Period	1.0-2.5	1.75 ± 0.17
1st Instar	1.25-2.75	2.15 ± 0.13
2nd Instar	1.5-3.5	2.50 ± 0.20
3rd Instar	3.5-4.75	4.15 ± 0.12
Pupa	6.0-10.0	8.10 ± 0.36
Pre-Oviposition Period	7.0-13.0	10.60 ± 0.60
Oviposition Period	3.0-9.0	6.00 ± 0.54
Post-Oviposition Period	1.0-5.0	3.00 ± 0.24
Male Longevity	16.0-22.0	18.70 ± 0.62
Female Longevity	19.0-29.0	23.10 ± 0.92
Sex Ratio	92-125	117.7 ± 1.27

Table 3: Duration of different stages of *B. dorsalis*

*SE = Standard Error.

Values are average of 10 observations in 3 replications.

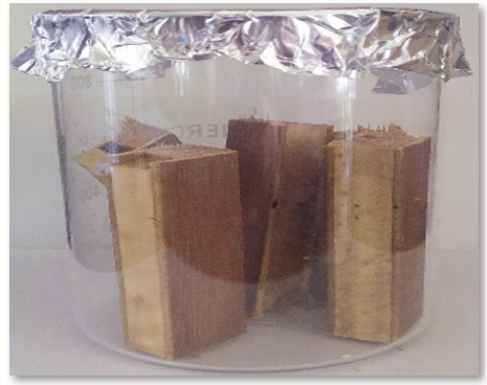
The fruit fly, *B. dorsalis* preferably chose physiologically mature fruits which were about to ripen for oviposition (Figure 4). The fly punctured the fruits at a number of places; however all the punctures didn't contain eggs inside. The punctured site became depressed and the fruit was deformed by many such depressions (Figure 4). The eggs of *B. dorsalis* were smooth, glistening white to creamish in colour, elliptical, elongated, slightly curved in and tapering at one end (Figure 3). The eggs were laid in clusters, embedded in the pulp of fruit vertically or slightly angled and twisted with each other (Figure 4). Morphometric study explained that the length and breadth of eggs ranged between 0.85-2.10 mm and 0.15-0.30 mm, respectively (Table 2). The incubation period recorded was 1.75 ± 0.17 days (Table 3) [16]. reported incubation period ranged between 1-2 days with an average of 1.61 ± 0.51 days. [17] reported that incubation period was in range of 1-2.3 days with an average of 1.50 ± 0.48 days. [18,19] also reported the incubation with a range of 2-4 days. So, the present results are in more or less concordance with the listed workers. The slight variation may be due to the climatic as well as zonal difference that affect the life cycle of the *B. dorsalis*.



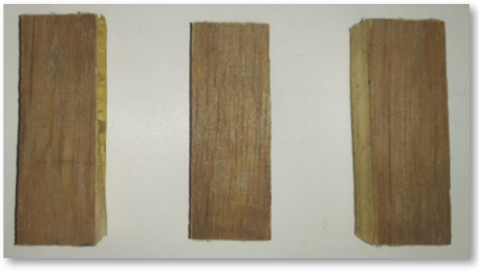
c)

d)

Figure 2: Different septa used in MAT's a) Soaking of septa; b) Septa size: 8*2*1.8 cm^3; c) Septa size: 4*2*1.8 cm^3; d) Septa: Standard Palam Trap.



a)



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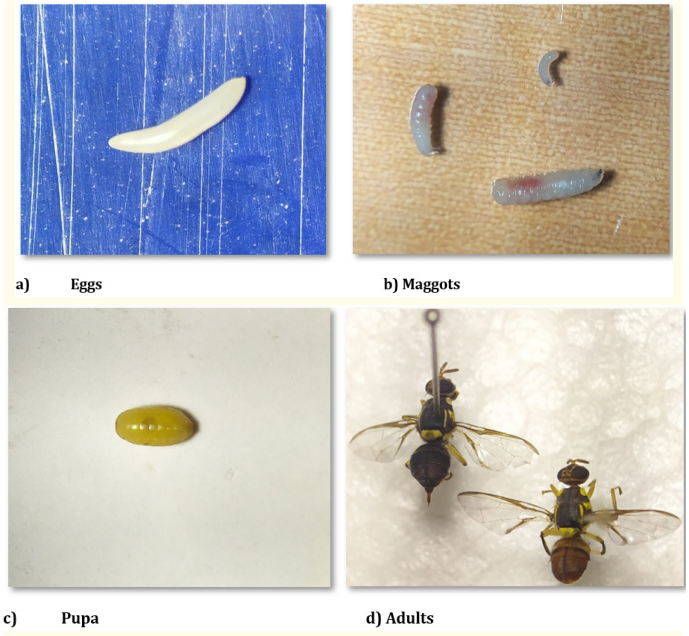

a) Eggs b) Maggots

c) Pupa d) Adults

Figure 3: Developmental stages of Bactrocera dorsalis Hendel a) Eggs; b) Maggots; c) Pupa; d) Adults.

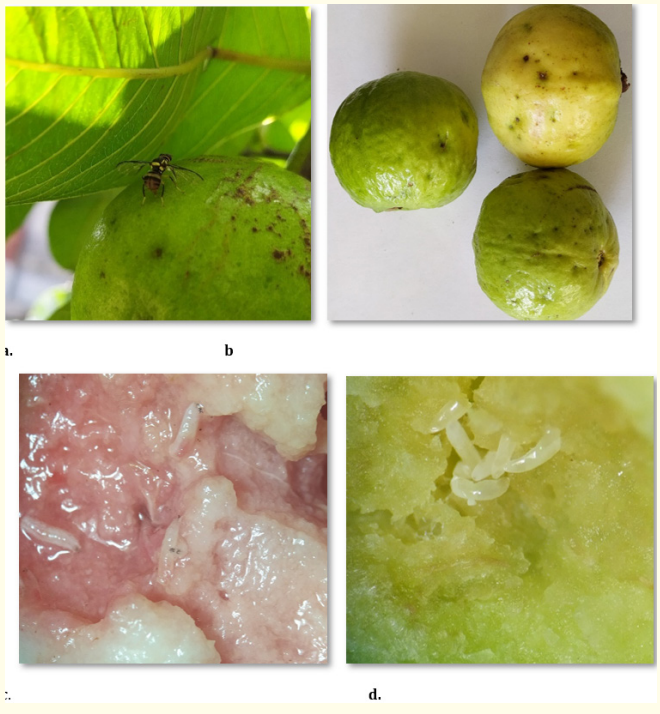

Figure 4: a) Egg laying female b) egg mass along with oviposition punctures; c,d egg masses and maggots inside pulp.

The maggots of *B. dorsalis* were seen to pass through three instars under laboratory conditions (Figure 3). The newly hatched young maggots were found to be sluggish but after feeding for a few hours, became active and bored into the pulp of fruit for feeding. After being fully developed, the maggots bored holes to exit out of the fruit and jumped to the ground for pupation. As a result of infestation, the fruits became distorted, rotten and completely unfit for consumption. The developmental period was 6-10 days with mean value of 8.1 ± 0.36 days for last instar (Table 3). [16] showed that length, breadth and duration of 3rd instar maggots varied from 7 to 8 mm with an average of 7.69 ± 0.72 mm, 3 to 4 mm with an average of 3.58 ± 0.25 mm and 2 to 3 days with an average of 2.75 ± 0.54 days, respectively. [18] Found that length and breadth of 3rd instar larvae was 8.60 ± 0.48 mm and 1.06-1.79 mm, respectively with duration ranging from 3.83 to 4.66 days.

The freshly formed pupae were found to be yellowish white to reddish yellow in colour initially and later they tuned to light golden yellow to honey brown colour (Figure 3). The pupae were barrel shaped and had 11 segments with last abdominal segment being little more prominent. The present investigations indicated that morphometric measurements of pupae recorded was about 4.61 ± 0.06 mm in length and 2.04 ± 0.03 mm in width (Table 2). The pupal stage lasted for 6-10 days with a mean of 8.1 ± 0.36 days (Table 3). Results of [20] support the mean pupal length to be 4.76 ± 0.02 mm and breadth to be 2.12 ± 0.03 mm.

B. dorsalis adults emerged from the pupa by pushing the upper end of the pupa and came out by bursting the pupal case. Later on, it slowly crawled through sand and soil to reach the surface. The newly emerged adult looked faint and sluggish; however, after sometime the wings were found fully opened by fluttering movement. The wings of adults consisted of continuous black marking on coastal margin, which was typical character to identify the *B. dorsalis.* The hind wings were modified into short halteres (Figure 4). In male, the abdomen was blunt while, it was developed into pointed ovipositor in case of female. Moreover, the male flies were slightly smaller than female flies. The length and breadth (wing expanse) of the male adult varied from 6.39 to 8.21 mm and 11.46 to 12.40 mm, respectively (Table 2). The longevity of male was between 16-22 days. The adult females were easily distinguishable by the presence of tapering yellow striped abdomen extending into pin like ovipositor and comparatively larger than the males. All these results are in accordance to that of, [16-18,20,21]. (21, 18, 16, 17, 20). The total life cycle from egg to adult emergence was recorded to be 18 to 23 days, with a mean of 20.3 ± 2.82 days in the present study. Results of the present study with regard to duration of different life stages of oriental fruit fly are in agreement with [21-23]. The sex ratio of male: female was recorded to be 1:1.26.

Seasonal abundance of fruit fly in the Low and Shivalik hills of Himachal Pradesh

From the figure 5, it is precipitable that on an average, the population of *B. dorsalis* dominated (1760.59/trap/year) over *B. zonata* (1130.05/trap/year). Maximum population of *B. dorsalis* was recorded in the month of September (398.90/trap) followed by August (288.61/trap) and July (270.66/trap), which concurred with the ripening of different mango and guava cultivars. The maximum population of *B. zonata* was observed in the month of September (230.55/trap) followed by August (221.15/trap) and July (212.05/trap), coinciding with the ripening of different peach cultivars during this time. During the winter months *i.e.* January-February, the all-time low population of both these species was logged.

Evaluation of different Male Annihilation Techniques (MATs) July 2019

Table 4 displays the information pertaining to the assessment of several male annihilation techniques (MATs) in July. Of the seven treatments that were tested for fruit fly capture, T7, which

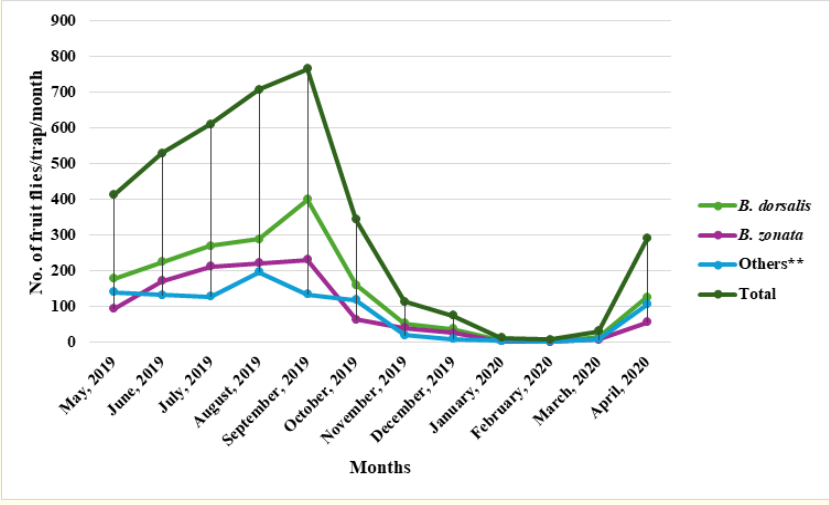

Figure 5: Seasonal variation of fruit fly species infesting Guava in Himachal Pradesh during various months of the year (2019-2020).

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

Treatments		Catches of fruit fly/trap/month			Mean
		*Bactrocera dorsalis**	*Bactrocera zonata**	*Bactrocera spp***	
T_1	Palam Trap	84.33 (9.23)	67.66 (8.28)	48.00 (6.96)	66.66 (8.16)
T_2	Methyl Eugenol (2ml) + Ethanol (3ml) + Malathion (0.5ml)	69.00 (8.36)	54.33 (7.43)	42.66 (6.60)	55.33 (7.46)
T_3	Methyl Eugenol (2ml) + Ethanol (3ml) + Cypermethrin (0.5ml)	37.33 (6.17)	25.00 (5.09)	21.00 (4.68)	27.77 (5.31)
T_4	Methyl Eugenol (2ml) + Ethanol (3ml) + Spinosad (0.5ml)	63.00 (7.99)	37.33 (6.18)	28.00 (5.38)	42.77 (6.52)
T_5	Methyl Eugenol (4ml) + Ethanol (6ml) + Cypermethrin (1ml)	100.33 (10.06)	82.33 (9.12)	67.00 (8.24)	83.22 (9.14)
T_6	Methyl Eugenol (4ml) + Ethanol (6ml) + Spinosad (1ml)	140.00 (11.86)	102.66 (10.17)	84.33 (9.23)	109.00 (10.42)
T_7	Methyl Eugenol (4ml) + Ethanol (6ml) + Malathion (1ml)	177.66 (13.36)	135.66 (11.68)	98.66 (9.97)	137.33 (11.67)
Mean		95.95 (9.58)	72.14 (8.28)	55.66 (7.29)	---

Table 4: Evaluation of different MATs at Himachal Pradesh during July 2019.

*Mean of 3 replications

**Among *Bactrocera spp. Bactrocera scutellaris* was observed as major one.

T_1 = Standard Palam Trap

T_2-T_4 = septa size 4 × 2 × 1.8 cm^3

T_5-T_7 = septa size 8 × 2 × 1.8 cm^3

$CD_{(0.05)}$

Treatment (T): (0.30)

Species (S): (0.19)

T×S: (0.51)

consisted of methyl eugenol (4 ml) + ethanol (6 ml) + malathion (1 ml), had the highest average catches (137.33 fruit flies/trap/week). This was followed by T6 (methyl eugenol (4 ml) + ethanol (6 ml) + spinosad (1 ml), T5 (methyl eugenol (4 ml) + ethanol (6 ml) + cypermethrin (1 ml), and T1 (palam trap), which produced significantly higher averages (fruit flies/trap/week) than the other treatments. T3 - 2 ml of methyl eugenol + 3 ml of ethanol + 0.5 ml of cyclomethrin exhibited the fewest captures which was followed by T4 - 2 ml of methyl eugenol + 3 ml of ethanol + 0.5 ml of spinosad, or 42.77 fruit flies/trap/week. It is perceptible from the table, that on an average, *Bactrocera dorsalis* dominated among the different species (95.95 fruit flies/trap/week) followed by *B. zonata* (72.14 fruit flies/trap/week) and *B. scutellaris* (55.66 fruit flies/trap/week). Maximum population of *B. dorsalis* was found in T_7 (177.66 fruit flies/trap/week) followed by T_6 (140.00 fruit flies/trap/week) and T_5 (100.33 fruit flies/trap/week). Lowest population of *B. dorsalis* was noted down in T_3 (37.33 fruit flies/trap/week) followed by T_4 (63.00 fruit flies/trap/week). Similar trend was observed in case of *B. zonata* and other species *i.e. B. scutellaris.* However, *B. zonata* number was higher than *B. scutellaris* in mean population of fruit fly among different treatments (Table 4).

August 2019

Table 5 displays the information pertaining to the assessment of several male annihilation techniques (MATs) in August. Out of the seven treatments that were tested for fruit fly capture, T7 had the highest average catches (216.88 fruit flies/trap/week) followed by T6, T5 and T1 (Table 5). It is perceptible from the table, that on an average, *Bactrocera dorsalis* dominated among the different species (163.04 fruit flies/trap/week) followed by *B. zonata* and *B. scutellaris*. The highest number of *B. dorsalis* fruit flies/trap/week (282.33) was recorded in T7, with the highest numbers in T6 (240.66) and T¬5 (198.66) fruit flies/trap/week. T3 had the lowest *B. dorsalis* population (52.33 fruit flies/trap/week), whereas T4 had the highest population (82.00 fruit flies/trap/week). A comparable pattern was noted for *B. zonata* and more species, such as *B. scutellaris*. In contrast, *B. zonata* outnumbered *B. scutellaris* in the mean fruit fly population across all treatments.

Treatments		Catches of fruit fly/trap/month			Mean
		Bactrocera dorsalis*	***Bactrocera zonata****	***Bactrocera spp****	
T_1	Palam Trap	161.00 (12.71)	100.33 (10.06)	75.00 (8.71)	112.11 (10.49)
T_2	Methyl Eugenol (2ml) + Ethanol (3ml) + Malathion (0.5ml)	124.33 (11.19)	89.66 (9.52)	57.66 (7.64)	90.55 (9.45)
T_3	Methyl Eugenol (2ml) + Ethanol (3ml) + Cypermethrin (0.5ml)	52.33 (7.27)	26.66 (5.25)	19.66 (4.54)	32.88 (5.69)
T_4	Methyl Eugenol (2ml) + Ethanol (3ml) + Spinosad (0.5ml)	82.00 (9.10)	53.33 (7.34)	38.33 (6.22)	57.88 (7.56)
T_5	Methyl Eugenol (4ml) + Ethanol (6ml) + Cypermethrin (1ml)	198.66 (14.13)	128.33 (11.35)	93.33 (9.70)	140.11 (11.73)
T_6	Methyl Eugenol (4ml) + Ethanol (6ml) + Spinosad (1ml)	240.66 (15.54)	165.66 (12.90)	116.00 (10.81)	174.11 (13.08)
T_7	Methyl Eugenol (4ml) + Ethanol (6ml) + Malathion (1ml)	282.33 (16.83)	206.66 (14.40)	161.66 (12.71)	216.88 (14.65)
Mean		163.04 (12.39)	110.09 (10.12)	80.23 (8.62)	---

Table 5: Evaluation of different MATs at Himachal Pradesh during August 2019.

*Mean of 3 replications

**Among *Bactrocera spp. Bactrocera scutellaris* was observed as major one.

T_1 = Standard Palam Trap

T_2-T_4 = septa size 4 × 2 × 1.8 cm^3

T_5-T_7 = septa size 8 × 2 × 1.8 cm^3

$CD_{(0.05)}$

Treatment (T): (0.43)

Species (S): (0.28)

T × S: (0.74)

September 2019

The data related to evaluation of different male annihilation techniques (MATs) during September have been presented in Table 6. Out of seven treatments tested for capturing of fruit fly, T_7 showed on an average highest catch (246.66 fruit flies/trap/week), followed by other treatments (Table 6). On an average, *B. dorsalis* dominated among the different species (201.33 fruit flies/trap/week) followed by *B. zonata* (118.23 fruit flies/trap/week) and *B. scutellaris* (76.90 fruit flies/trap/week). Maximum population of *B. dorsalis* was found in T_7 (360.66 fruit flies/trap/week) followed by T_6 and T_5 (Table 6). Similar trend was observed in case of *B. zonata* and other species *i.e. B. scutellaris.* However, *B. zonata* number was higher than *B. scutellaris* in mean population of fruit fly among different treatments.

Treatments		Catches of fruit fly/trap/month			Mean
		*Bactrocera dorsalis**	*Bactrocera zonata**	*Bactrocera spp***	
T_1	Palam Trap	196.66 (14.05)	102.33 (10.14)	75.66 (8.75)	124.88 (10.98)
T_2	Methyl Eugenol (2ml) + Ethanol (3ml) + Malathion (0.5ml)	162.00 (12.76)	72.66 (8.56)	43.66 (6.63)	92.77 (9.32)
T_3	Methyl Eugenol (2ml) + Ethanol (3ml) + Cypermethrin (0.5ml)	76.33 (8.78)	30.33 (5.56)	16.66 (4.18)	41.11 (6.17)
T_4	Methyl Eugenol (2ml) + Ethanol (3ml) + Spinosad (0.5ml)	106.33 (10.35)	52.00 (7.27)	29.33 (5.50)	62.55 (7.71)
T_5	Methyl Eugenol (4ml) + Ethanol (6ml) + Cypermethrin (1ml)	228.33 (15.13)	139.66 (11.84)	105.00 (10.29)	157.66 (12.42)
T_6	Methyl Eugenol (4ml) + Ethanol (6ml) + Spinosad (1ml)	279.00 (16.72)	196.33 (14.04)	123.00 (11.12)	199.44 (13.96)
T_7	Methyl Eugenol (4ml) + Ethanol (6ml) + Malathion (1ml)	360.66 (19.01)	234.33 (15.33)	145.00 (12.08)	246.66 (15.47)
Mean		201.33 (13.83)	118.23 (10.39)	76.90 (8.36)	---

Table 6: Evaluation of different MATs at Himachal Pradesh during September 2019.

*Mean of 3 replications

**Among *Bactrocera spp. Bactrocera scutellaris* was observed as major one.

T_1 = Standard Palam Trap

T_2-T_4 = septa size 4 × 2 × 1.8 cm^3

T_5-T_7 = septa size 8 × 2 × 1.8 cm^3

$CD_{(0.05)}$

Treatment (T): (0.51)

Species (S): (0.33)

T × S: (0.88)

Discussion

Worldwide, *B. dorsalis* is a serious fruit pest that results in large monetary losses. Establishing thresholds for management, figuring out the pest's distribution, assessing the effectiveness of control methods, and identifying the important fruit fly species that are present in an orchard all depend on monitoring [13]. Pheromone traps with male lures as the primary attractants are used in monitoring systems [24]. One parapheromone that attracts males is methyl eugenol, a 4-allyl-1,2-dimethoxybenzene-carboxylate, which is mostly used in India for *Bactrocera* species surveillance and monitoring [25]. Methyl eugenol has proven useful in surveillance and monitoring programs due to its high levels of attraction to male *B. dorsalis*.

In seasonal fluctuation, the population was at its apex in the month of September followed by August and July. The female fruit flies outnumbered compared to the male fruit flies. [26] observed the peak incidence of fruit flies from July to September. At Bangalore, [27] recorded three distinct population peaks of *B. dorsalis* during, March-April, May-June and September-October. [28] saw a decline in population of *B. dorsalis* from November to early May under Taiwan conditions. [29] noticed the peak incidence from June to September. However, in winters a decline in the population was observed. These findings are in conformity with the present results. [30] noticed the peak activity of fruit flies from August to October, which synchronized with the maturity period of guava. In Pakistan, [31] studied *Bactrocera* spp. and noticed maximum infestation 10.76 and 14.74%, during August and September months, respectively. Hence, the present data is in accordance with the findings of these workers. The fruit fly population starts to decrease in Himachal Pradesh after September that might be due to the fruit maturity of Guava and also due to the lowering of temperature in winter months.

The results of morphometric studies, revealed that average length and width of egg, full-grown maggots and pupae were 1.30 ± 0.13 mm and 0.23 ± 0.01 mm, 8.28 ± 0.13 and 1.65 ± 0.70 mm, 4.61 ± 0.06 mm and 2.40 ± 0.03 mm, respectively and length of adult flies measured 7.57 ± 0.20 and 8.38 ± 0.20 mm in male and female, respectively. The biological study evidenced that developmental period from immature to adult females varied from 19 to 29 days with a mean of 23.10 ± 0.92 days and that of males ranged between 16 to 22 days and averaged for 18.70 ± 0.62 days.

Among many Male Annihilation Techniques tested on fruit flies, the combination of Methyl Eugenol (4 ml) + Ethanol (6 ml) + Malathion (1 ml) showed a significant improvement over previous treatments, with a septum size of 8 × 2 × 1.8 cm3. *B. dorsalis* had the largest population of the three species found in fruit fly traps, followed by *B. zonata* and *B. scuttelaris*. Several sized plywood septa were employed in the current study to absorb insecticide, ethanol, and parapheromone. After testing various materials for recording the persistence of para-pheromones, [32,33]. found that plywood, strawboard, and acacia blocks demonstrated higher efficacy and were excellent choices for monitoring. Several researchers have observed that plywood septa soaked with ethanol solvent, methyl eugenol, and malathion are highly successful at keeping fruit flies away from orchards [34-36]. Our research revealed that the septa of ply wood impregnated with the same had the highest fruit fly capture rates. Therefore, the outcomes of the workers mentioned above support the current conclusions. [37] found that the increased efficiency of spinosad impregnated septum and methyl eugenol was consistent with the current findings. They claimed that spinosad was a potentially effective replacement for the liquid organophosphate formulation now in use in cue-lure bucket traps and methyl eugenol for the area-wide control of *B. cucurbitae* and *B. dorsalis.*

The most effective and widely used way of controlling fruit flies is the use of male lures, or the Male Annihilation Technique [9-10]. This procedure eliminates male flies and decreases the likelihood that the insect will mate. The females have extremely few offspring as a result. This leads to a drop in the wild population in the target area and ultimately to its eradication. Using 0.1% Methyl eugenol baited traps in the guava orchard, [38] found a substantial drop in the *B. dorsalis* population. Methyl eugenol traps are highly successful for monitoring *B. dorsalis* and *B. zonata* fruit flies [39]. The present investigation, also revealed that more the dose of methyl eugenol, the more fruit fly catches were there. The results of present findings got substantial support from [40] who recorded that mean number of *B. dorsalis* fruit flies caught in traps baited with 0, 2, 10 and 20 drops of methyl eugenol were significantly different, the number of fly catches increased with increasing dose.

Based on the aforementioned findings, male annihilation tactics provide one of the best approaches for controlling fruit flies. For the purpose of managing fruit flies, an integrated strategy that incorporates cultural methods including gathering and deeply bury-

ing fallen and infested fruits, summer time tillage around field trees, and fruit fly traps can be used. This environmentally benign method has many benefits, including lower labor costs, cheaper and safer than chemical pesticides, fruit free of pesticide residue, and no negative effects on the environment, human health, or natural enemies.

Conclusion

In seasonal fluctuation, the population was at its apex in the month of September followed by August and July. The biological study evidenced that developmental period from immature to adult females varied from 19 to 29 days and that of males ranged between 16 to 22 days and averaged for 18.70 ± 0.62 days. Out of different Male Annihilation Techniques evaluated against fruit fly, Methyl Eugenol (4ml) + Ethanol (6ml) + Malathion (1ml) with septum size (8 × 2 × 1.8 cm^3), was notably superior to other treatments. Among the three species captured in fruit fly traps, the population of *B. dorsalis* was maximum, followed by *B. zonata* and *B. scuttelaris.*

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