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Research Article

Monitoring of the Fruit Flies (*Bactrocera* spp.) Infesting Jujube Orchard using Static Spinosad Traps

Ariz Muhammad Pirzado[1], Bhai Khan Solangi[1], Din Muhammad Soomro[1*], Agha Mushtaque Ahmed[1], Khadim Hussain Wagan[2], Faiza Abbasi[3], Jawad Hyder Soomro[1], Shafee Muhammad[1], Abdul Rahman Tunio[1] and Nimra Razzaq[4]

[1]Department of Entomology, Faculty of Crop Protection, Sindh Agriculture University, Tandojam
[2]Department of Plant Pathology, Faculty of Crop Protection, Sindh Agriculture University, Tandojam
[3]Department of Statistics, Faculty of Agriculture Social Science, Sindh Agriculture University, Tandojam
[4]Department of Agronomy, Faculty of Agriculture, University of Agriculture Faisalabad, Faisalabad

Abstract: Fruit flies (*Bactrocera* spp.) are regarded as serious insect pests of fruits and vegetables in the world. The goal of this study was to examine the effect of spinosad traps on *Bactrocera* spp. at different heights 0, 1, 2, and 3 m on jujube tree during 2020-2021. Flies' populations were counted weekly. The results revealed that the highest population of *B. zonata* (225.6 flies) were recorded at 2 m height on (22 October, 2020) and the lowest ones (21.6 flies) were recorded at the ground level (0 m height) during (4 February, 2021). However, the overall maximum catches were 158.95 at 2 m height and minimum was 68.72 at the ground level. Similarly, the maximum population of *B. dorsalis* was (50.5 flies) at 2 m height during (9 October, 2020), but the minimum (2.5 flies) was in the ground level during (4 February, 2021). The overall highest *B. dorsalis* catches were (43.50 flies) at 2 m height and the lowest was (3.55 flies) at ground level. The population of *B. zonata* correlated positively (r= 0.2939**) with temperature, but negatively (r= -0.0223^{NS}) with relative humidity. However, *B. dorsalis* populations was positive correlated with both of the temperature and relative humidity (r= 0.0261** and r= 0.0091^{NS}, respectively). Ultimately, pheromone traps (Spinosad+Methyl eugenol) at 2 m height are highly recommended to catches both fruit flies (*B. zonata* and *B. dorsalis*) in Jujube Orchards.

Keywords: *Bactrocera zonata, Bactrocera dorsalis*, Jujube, Methyl eugenol, Spinosad.

1. INTRODUCTION

Jujube (*Ziziphus mauritiana* Lamk.), known as "Ber or apple of the desert", is a member of the Rhamnaceae (Buckthorn) family native to China and the Indo-Pak Subcontinent. It thrives in the semi-arid and arid zones marginal ecosystems. Ber's xerophytic characteristics such as its tap root system, the presence of scales on buds, and its deciduous nature in the heat of summer, have made it a profitable crop [1]. Besides, Jujube is widely grown in Pakistan, although it thrives best in the ecological zones of Hyderabad, Khairpur, Multan, Sargodha, and Lahore Divisions. Hyderabad is well-known for its high-quality fruit exports to the Middle East. The tree is tough, drought-resistant, and can grow on poor alkaline soils without a lot of water, as well as on soils where other fruit trees can't grow [2]. Ber is grown on 5425 hectares in Pakistan, with an annual output of 27950 tonnes [3].

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*Corresponding Author: Din Muhammad Soomro <dinmuhammad1177@gmail.com>

Fruit flies are considered as one of the most damaging agricultural pests around the globe and cause huge threats to horticultural crops, both fruits and vegetables [4-6]. There are about 4000 species of fruit flies in the family of Tephritidae throughout the world, out of which around 350 species have great importance [7]. Tephritid fruit flies cause 90 to 100 % yield loss in fruits and vegetables depending upon several factors such as area season, variety and their population [8]. Fruit flies caused direct loss in the form of yield and indirect loss such as reduction in trade and export prospect [9].

Fruit flies, *Bactrocera* spp. (Diptera: Tephritidae) are frequently found in mango, citrus, and guava plantations [10] and they are often regarded as the world's most damaging insect pests of fruits and vegetables. Many important commercial crops are among the flies' hosts, which come from a broad range of plant groups [11-12]. Their direct damage ranging from 30 to 80 percent based on the fruit host, type, location, and season [13]; decreasing crop output either numerically or qualitatively [14-15].

Bactrocera zonata (Sunder) and *B. dorsalis* (Hendel) are the most damaging fruit flies among 400 species found throughout the globe [16]. They overwinter as adults and cause harm to fruits by infesting them. Their maggots feed within the host fruit after female flies' deposit eggs in fragile and sensitive fruit tissues [17]. In Pakistan, 11 species of the genus *Bactrocera* have been identified, out of a total of 43 species. The most common flies are *B. zonata, B. dorsalis* and *B. cucurbitae,* which infest apple (*Malus domestica*), bitter ground *(Mongifera indica*), muskmelon (*Cucumis melon*) and snack ground (*Trichosanthes cucumerina*) [18-19].

Monitoring accumulated degree days are available tool for predicting insect activity and timing pest management practices. Temperature and relative humidity are important abiotic factors affecting the survival and developmental rates of fruit flies [20]. This research work was undertaken to study the fruit flies' species diversity, incidence pattern and their relationship with different weather parameters in relation to static spinosad traps at different heights in Jujube orchards.

2. MATERIALS AND METHODS

2.1 Experimental Site

The experiment was conducted at Jujube orchard farm, Agriculture Research Institute (ARI), Tandojam for the monitoring of fruit flies, *Bactrocera* spp. during the year 2020-21. The orchard size was 8 acres.

2.2 Experimental Design and Treatments

The experiment was laid out in Randomized Complete Block Design (RCBD) was used with five replications for each tested height. The pheromone trap baited with static spinosad (Spinosad+Methyl eugenol) was used for catching the male fruit flies (*B. zonata* and *B. dorsalis*) at different heights on jujube trees. Four treatments were assessed in this study:

T_1 = Pheromone traps installed on a ground surface
T_2 = Pheromone traps installed at 1 m height
T_3 = Pheromone traps installed at 2 m height
T_4 = Pheromone traps installed at 3 m height

2.3 Procedure of Experiment

The male adult population of fruit flies was counted weekly basis. The pheromone traps were (36 x 11 x 16 cm) in size, cylindrical in form, with a top cover and two openings spaced evenly in opposing directions. Cotton wicks were utilized to absorb 3 g of static spinosad therapy and were wrapped in wire to connect with the trap. These traps were replaced every 35 days to ensure that the chemical used to attract the fruit flies was fresh. At weekly intervals, the number of attracted male flies in traps was tallied, and the species was recognized.

2.4 Statistical Analysis

The collected data were statistically analyzed using Statistix 8.1 software. Means treatments were compared with LSD test at $P< 0.05$ level.

3. RESULTS

The weekly population of *B. zonata* on different heights is presented in (Table 1). The highest

Table 1. Weekly mean population of *B. zonata* on different trapping heights at Jujube orchard

Weeks	Trapping height			
	0 m (Ground surface)	1 m	2 m	3 m
15/10/2020	131.6 ± 3.7 ^{ab}	154.1 ± 7.5 ^{a}	221.3 ± 10.9 ^{ab}	197.6 ± 11.7 ^{ab}
22/10/2020	138.8 ± 5.6 ^{ab}	157.3 ± 8.9 ^{a}	225.6 ± 15.6 ^{a}	206.6 ± 14.3 ^{a}
29/10/2020	142.6 ± 4.5 ^{a}	153.3 ± 9.7 ^{a}	220.8 ± 14.1 ^{ab}	194.6 ± 14.4 ^{ab}
05/11/2020	134.2 ± 5.6 ^{ab}	144.6 ± 2.0 ^{a}	208.2 ± 17.1 $^{a-c}$	189.8 ± 12.3 ^{ab}
12/11/2020	125.6 ± 7.5 ^{bc}	140.2 ± 7.0 ^{ab}	201.8 ± 15.1 $^{a-d}$	177.4 ± 15.2 $^{a-c}$
19/11/2020	115.6 ± 5.1 ^{cd}	122.7 ± 9.6 ^{bc}	183.8 ± 10.6 $^{a-e}$	166.4 ± 15.6 $^{b-d}$
26/11/2020	108.7 ± 5.6 ^{d}	111.5 ± 8.7 ^{cd}	174.8 ± 21.4 $^{a-f}$	153.2 ± 18.6 $^{c-e}$
03/12/2020	87.7 ± 6.2 ^{e}	102.2 ± 4.5 $^{d-f}$	163.4 ± 20.3 $^{c-g}$	144.6 ± 8.8 $^{d-f}$
10/12/2020	80.2 ± 8.5 ^{ef}	91.6 ± 7.2 $^{e-h}$	158.2 ± 23.4 $^{c-g}$	135.4 ± 8.9 $^{d-g}$
17/12/2020	67.0 ± 5.5 $^{f-h}$	86.2 ± 7.2 $^{f-i}$	149.6 ± 18.3 $^{d-g}$	124.6 ± 7.9 $^{e-i}$
24/12/2020	62.4 ± 4.9 ^{gh}	81.4 ± 8.3 $^{g-k}$	127.0 ± 20.7 ^{fg}	118.2 ± 8.9 $^{f-k}$
31/12/2020	60.9 ± 4.6 ^{h}	77.8 ± 5.7 $^{h-k}$	133.8 ± 30.6 $^{e-g}$	83.4 ± 2.9 $^{l-n}$
07/01/2021	39.8 ± 4.6 ^{jk}	63.6 ± 4.8 ^{k}	119.4 ± 18.1 ^{g}	89.8 ± 9.1 $^{j-n}$
14/01/2021	35.8 ± 6.1 $^{j-l}$	66.6 ± 5.3 ^{k}	122.8 ± 23.9 ^{fg}	79.8 ± 15.8 ^{mn}
21/01/2021	24.2 ± 3.5 ^{lm}	63.2 ± 3.5 ^{k}	117.3 ± 20.8 ^{g}	58.0 ± 7.4 ^{n}
28/01/2021	23.6 ± 4.0 ^{lm}	64.4 ± 3.6 ^{k}	123.1 ± 14.4 ^{fg}	86.4 ± 13.4 $^{k-n}$
04/02/2021	21.6 ± 3.9 ^{m}	67.9 ± 4.2 ^{jk}	126.4 ± 18.8 ^{fg}	93.4 ± 10.9 $^{i-m}$
11/02/2021	26.4 ± 3.9 $^{k-m}$	76.8 ± 4.2 $^{h-k}$	141.7 ± 18.5 $^{e-g}$	98.8 ± 10.0 $^{h-m}$
18/02/2021	24.4 ± 3.2 ^{lm}	71.8 ± 5.7 $^{i-k}$	134.1 ± 9.1 $^{e-g}$	105.8 ± 6.4 $^{g-m}$
25/02/2021	25.0 ± 3.3 ^{lm}	75.4 ± 8.2 $^{h-k}$	141.6 ± 22.5 $^{e-g}$	112.8 ± 10.2 $^{f-l}$
04/03/2021	29.6 ± 2.1 $^{k-m}$	85.6 ± 7.5 $^{f-j}$	143.2 ± 17.9 $^{e-g}$	116.4 ± 8.3 $^{f-k}$
11/03/2021	36.8 ± 4.1 $^{j-l}$	92.6 ± 5.1 $^{e-h}$	145.0 ± 18.8 $^{e-g}$	122.6 ± 15.0 $^{e-i}$
18/03/2021	44.6 ± 4.6 ^{ij}	93.2 ± 5.8 $^{d-h}$	156.4 ± 16.1 $^{c-g}$	118.8 ± 9.8 $^{f-k}$
25/03/2021	55.4 ± 3.7 ^{hi}	97.8 ± 6.1 $^{d-g}$	165.8 ± 19.2 $^{c-g}$	119.6 ± 11.3 $^{f-j}$
01/04/2021	75.6 ± 4.8 $^{e-g}$	106.5 ± 5.2 $^{c-e}$	168.6 ± 21.0 $^{b-g}$	131.0 ± 11.7 $^{e-h}$

Different letters within a column indicate significant difference (Fisher's Protected LSD test: P<0.05)

trapping was observed (206.6 ± 14.3 flies) at 3 m height on 22 October, 2020, while the lowest population was (58.0 ± 7.4 flies) on 21 January, 2021. Similarly, at the height of 1 and 2 m, the same trapping trend of peach fruit fly population was noted (157.3 ± 8.9 and 225.6 ± 15.6 flies, respectively) on 22 October, 2020. However, the least catching of male fruit flies was (63.2 ± 3.5 flies) at 1 m height, as well as (117.3 ± 20.8 flies) at 2 m on 21 January, 2021. Furthermore, the maximum weekly population (142.6 ± 4.5 flies) was recorded in ground level (0 m) during 29 October, 2020, but the minimum catch was (21.6 ± 3.9 flies) on 4 February, 2021. The analysis of variance (ANOVA) shows a significant difference (P<0.05) among all treatments during whole weeks. The overall trapping of male fruit flies at different heights are shown in (Figure 1). In this regard, the maximum male catches were recorded at 2 m trapping height, followed by 3 m and the lowest was on a ground level (0 m).

On the other hand, the weekly population of *B. dorsalis* on various trapping heights is shown in (Table 2). The maximum catching of male oriental fruit flies was counted (50.5 ± 3.3 flies) on 29 October, 2020 at 2 m height, but the minimum mean trapping was found (36.1 ± 3.9 flies) on 18 February, 2021. The same highly population trapping trend was (27.2 ± 2.6 flies) during 5 November, 2020, but the least population was (15.8 ± 2.9 flies) on 11 February, 2021 at 3 m height. At 1 m trapping height, the maximum mean population was (17.6 ± 3.1 flies) during 22 October, 2020, but the least one was (8.7 ± 0.7 flies) on 14 January, 2021.

At the ground level (0 m), the maximum

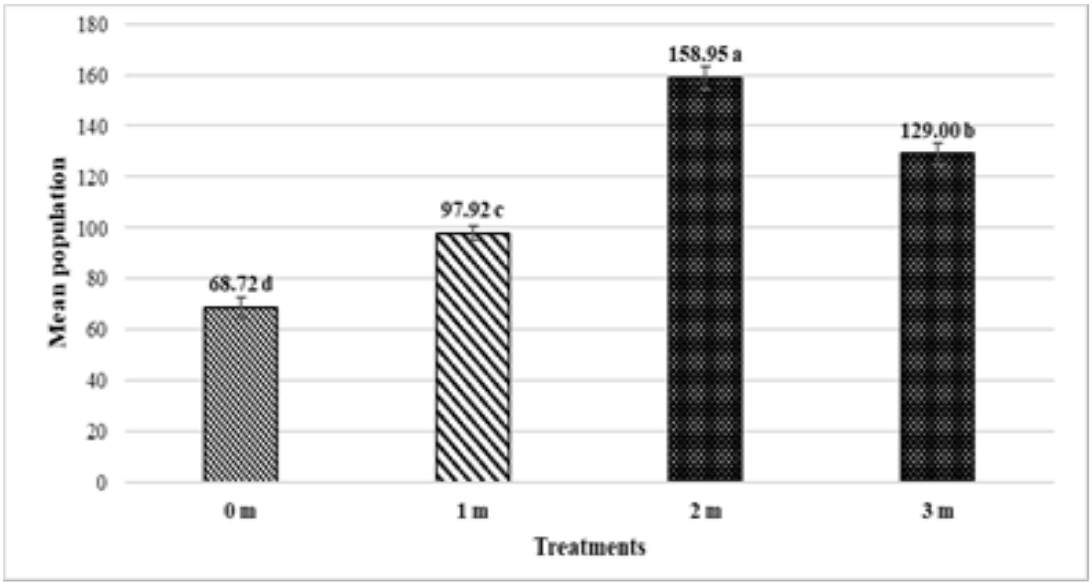

Fig. 1. Overall mean population of *B. zonata* at different trapping heights at Jujube orchard

Table 2. Weekly mean population of *B. dorsalis* on different trapping heights at Jujube orchard

Weeks	Trapping height			
	0 m (Ground surface)	1 m	2 m	3 m
15/10/2020	4.2 ± 0.7 $^{a-c}$	14.5 ± 1.4 $^{a-g}$	47.5 ± 3.7 ^{ab}	24.0 ± 2.9 ^{ab}
22/10/2020	3.9 ± 0.6 $^{a-d}$	17.6 ± 3.1 ^{a}	48.6 ± 4.2 ^{a}	25.4 ± 2.7 ^{ab}
29/10/2020	3.8 ± 0.6 $^{a-e}$	16.8 ± 1.9 ^{ab}	50.5 ± 3.3 ^{a}	26.2 ± 3.1 ^{ab}
05/11/2020	4.0 ± 0.5 $^{a-d}$	15.3 ± 1.9 $^{a-e}$	49.1 ± 4.9 ^{a}	27.2 ± 2.6 ^{a}
12/11/2020	3.9 ± 0.6 $^{a-e}$	12.3 ± 1.2 $^{b-i}$	45.7 ± 4.6 ^{ab}	25.8 ± 2.9 ^{ab}
19/11/2020	4.3 ± 0.5 ^{ab}	15.0 ± 2.0 $^{a-f}$	46.6 ± 6.0 ^{ab}	25.2 ± 2.7 ^{ab}
26/11/2020	4.6 ± 0.3 ^{a}	14.6 ± 2.8 $^{a-g}$	44.5 ± 4.6 ^{ab}	24.2 ± 2.3 ^{ab}
03/12/2020	3.4 ± 0.5 $^{a-f}$	12.7 ± 1.6 $^{b-i}$	45.4 ± 5.6 ^{ab}	23.2 ± 2.5 $^{a-c}$
10/12/2020	3.2 ± 0.4 $^{b-f}$	12.3 ± 1.2 $^{b-i}$	44.9 ± 4.9 ^{ab}	22.6 ± 2.2 $^{a-c}$
17/12/2020	3.9 ± 0.6 $^{a-d}$	10.1 ± 0.6 $^{g-i}$	42.3 ± 4.1 ^{ab}	24.0 ± 3.0 ^{ab}
24/12/2020	3.9 ± 0.3 $^{a-d}$	14.0 ± 2.5 $^{d-i}$	40.6 ± 5.0 ^{ab}	20.2 ± 3.5 ^{ab}
31/12/2020	3.6 ± 0.3 $^{a-e}$	10.3 ± 1.1 $^{g-i}$	42.4 ± 3.6 ^{ab}	20.0 ± 3.1 $^{a-c}$
07/01/2021	2.9 ± 0.4 $^{d-f}$	11.3 ± 1.0 $^{d-i}$	41.2 ± 4.4 ^{ab}	22.8 ± 2.6 $^{a-c}$
14/01/2021	3.4 ± 0.2 $^{a-f}$	8.7 ± 0.7 ^{i}	41.9 ± 2.8 ^{ab}	24.4 ± 2.5 ^{ab}
21/01/2021	2.7 ± 0.4 ^{ef}	10.5 ± 1.7 $^{f-i}$	39.9 ± 3.6 ^{ab}	20.8 ± 1.5 $^{a-c}$
28/01/2021	2.9 ± 0.1 $^{c-f}$	9.9 ± 1.1 ^{hi}	38.6 ± 3.9 ^{ab}	23.2 ± 2.5 $^{a-c}$
04/02/2021	2.5 ± 0.3 ^{f}	12.3 ± 0.5 $^{b-i}$	40.3 ± 3.0 ^{ab}	24.0 ± 3.4 ^{ab}
11/02/2021	2.9 ± 0.4 $^{c-f}$	13.2 ± 1.3 $^{a-i}$	38.6 ± 3.9 ^{ab}	15.8 ± 2.9 ^{c}
18/02/2021	2.9 ± 0.3 $^{d-f}$	10.6 ± 1.1 $^{e-i}$	36.1 ± 3.9 ^{b}	18.8 ± 2.4 ^{bc}
25/02/2021	3.5 ± 0.2 $^{a-f}$	11.9 ±1.7 $^{c-i}$	41.8 ± 3.8 ^{ab}	19.0 ± 2.3 ^{bc}
04/03/2021	3.4 ± 0.3 $^{a-f}$	13.9 ± 1.2 $^{a-h}$	43.3 ± 2.6 ^{ab}	19.2 ± 3.2 ^{bc}
11/03/2021	3.8 ± 0.3 $^{a-e}$	14.6 ± 1.7 $^{a-g}$	46.2 ± 6.1 ^{ab}	19.0 ± 2.4 ^{bc}
18/03/2021	3.7 ± 0.4 $^{a-f}$	16.2 ± 2.4 ^{abc}	41.0 ±4.2 ^{ab}	22.1 ± 1.9^{a-c}
25/03/2021	3.5 ± 0.5 $^{a-f}$	13.8 ± 1.2 $^{a-h}$	45.8 ± 5.9 ^{ab}	22.5 ± 3.3 $^{a-c}$
01/04/2021	3.8 ± 0.5 $^{a-e}$	15.6 ± 1.2 $^{a-d}$	44.7 ± 2.6 ^{ab}	21.6 ± 4.0 $^{a-c}$

Different letters within a column indicate significant difference (Fisher's Protected LSD test: P<0.05)

population of *B. dorsalis* was (4.6 ± 0.3 flies) on 26 November, 2020, but the minimum population was (2.5 ± 0.3 flies) during 4 February, 2021. The overall catching of *B. dorsalis* on different heights is presented in (Figure 2). In this regard, the highest male catches were counted at 2 m trapping height, followed by 3 m while the lowest catching was on a ground level (0 m).

Similarly, the result regarding trapping population of both fruit flies correlated with abiotic factors (temperature and relative humidity) is mentioned in (Table 3). A positive significantly relationship (0.2939**) was noted between the population of *B. zonata* and temperature but was negatively non-significant (-0.0223NS) with relative humidity %. For *B. dorsalis*, A positive relationship (0.0261** and 0.0091^{NS}) was with temperature and relative humidity, respectively.

Table 3. Pearson's correlation among *B. zonata* and *B. dorsalis* population with abiotic factors

Variables	*B. zonata*	*B. dorsalis*
Temperature (˚C)	r = 0.2939**	r = 0.0261**
Relative humidity (%)	r = -0.0223^{NS}	r = 0.0091**

**Significant; ^{NS}= Non-significant.

4. DISCUSSION

The present results revealed that the baited static spinosad (Spinosad+Methyl eugenol) trap placed at 2 m height caught the most fruit flies (*B. zonata* and *B. dorsalis*) in the Jujube Orchard. The population of *B. zonata* was found to be greater than *B. dorsalis*, during seasonal fruit fly infestation monitoring. Our findings were corroborated with those reported previously by Vistro *et al.* [21], who claimed that *B. zonata* was measured (61.38 flies) at a height of 2 m. On the other hand, weekly trap catches were recorded at 3 m (51.35), 1 m (43.03), and 0 m (38.09), respectively. In the same way, the highest weekly *B. dorsalis* at a height of 2 metres were 0.49, and 0.43, 0.36, and 0.29, respectively for 3 m, 1 m, and ground surface. Although, this work found the maximum population of *B. zonata* was observed (206.6 flies) at 3 m height on 22 October, 2020, but the minimum catches flies were (21.6 ± 3.9 flies) at 0 m (ground level) on 4 February, 2021. On the other hand, highest *B. dorsalis* was counted (50.5 ± 3.3 flies) on 29 October, 2020 at 2 m height, but the minimum population was (2.5 ± 0.3 flies) during 4 February, 2021 at 0 m (ground level). According to the findings of Solangi *et al.* [22], the maximum *B. zonata* was captures at 2 m height with (1428.4 flies), followed by 1 m, 3 m and 0 m (ground surface) with (1340.5, 1185.4, and 1177.3, respectively). However, the highest *B. dorsalis* 7.34 flies were counted at 2 m height, while lowest was noted 4.67 flies at 3 m height, followed by 0 m (ground surface) and 1 m with (6.29 and 4.96 flies). Similarly, Hasnain *et al.* [23] also observed that the maximum male fruit flies 515 was counted at 5 m height, while

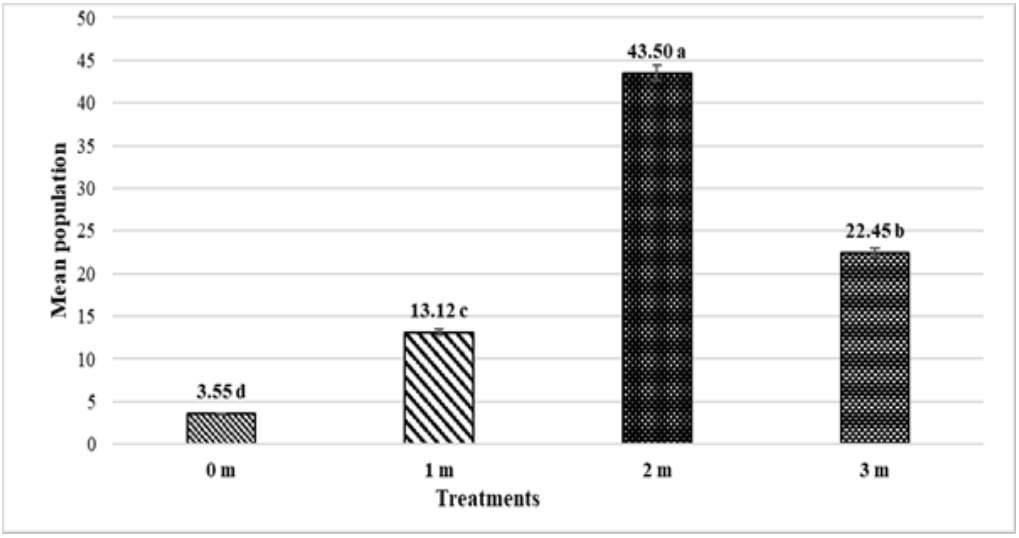

Fig. 2. Overall mean population of *B. dorsalis* on different trapping heights at Jujube orchard

minimum 315 flies were noted at 3 m height.

In addition, as reported by Wazir *et al.* [24], the highest population of fruit fly was recorded in July, while the lowest number was in January. However, as observed previously by Ahmad and Begum [25], the highest population density for fruit flies was discovered in methyl eugenol (382) in comparable to that of Gf 120 (197.2), while the lowest was found in Raspberry essence (23.6). Moreover, Darwish *et al.* [26] found that when methyl eugenol traps were placed at heights of 1 and 2 m, the guava fruit fly was highly captured. According to the observation by Singh and Sharma [27], the trap captures varied from 76.3 flies in the first week of June to 326.3 flies in the late week of July. According to the previous results noted by Khan *et al.* [28], Methyl eugenol traps catchs the most important fruit flies such as *B. dorsalis*, *B. zonata* and *C. vesuviana.*

Similarly, the result regarding trapping population of both fruit flies correlated with abiotic factors (temperature and relative humidity), a positive significantly relationship (0.2939**) was noted between the population of *B. zonata* and temperature but was negatively non-significant (-0.0223^{NS}) with relative humidity %. For *B. dorsalis*, a positive relationship (0.0261** and 0.0091^{NS}) was with temperature and relative humidity, respectively. According to the observation by Ye and Liu [29], to record the effect of abiotic factors on population of fruit flies three peaks, during the 27, 45, and 48th standard weeks, *B. dorsalis* was found in a guava orchard, whereas *B. correcta* reached its highest point during the 27-standard week, although it also reached two more high points during the 11 and 18 standard weeks, respectively.

According to Khoso *et al.* [30], the population of *Bactrocera* spp. (*B. dorsalis* and *B. zonata*) had a positive relation with wind velocity and temperature, while with mean relative humidity had a negative association. Besides, Khan and Naveed [31] exhibited that populations and temperature have a positive connection, whereas relative humidity has a slightly negatively. Das *et al.* [32] recorded the *B. dorsalis* had a significant positive correlation coefficient with the seasonal average maximum temperature (0.187), and a significant negative correlation coefficient with the lowest temperature (-0.087), morning relative humidity (-0.257), afternoon relative humidity (-0.511), and rainfall (-0.329). In a similar concept was noted in *B. zonata* with maximum temperature (0.543), minimum temperature (0.192), and rainfall (0.017), all had substantial positive correlations, whereas morning relative humidity (-0.241) and afternoon relative humidity (-0.215) had significant negative correlations. During the dry season, Vayssieres *et al.* [33] found the greatest influence on the population of Ceratitis cosyrawas, but the least impact was on the population of *B. invadancs*. The effect of daily rainfall on the population of *B. invadens* has been shown to be beneficial. Invaders, to be precise.

5. CONCLUSION & RECOMMENDATIONS

The present findings concluded that 2 m height showed maximum catches of both fruit flies (*B. zonata* and *B. dorsalis*) when installed pheromone traps (Spinosad+Methyl eugenol) in Jujube orchard. However, the minimum catches of both fruit flies were counted at 3 m, 1 m and 0 m (ground level) heights. Ultimately, the trap should be installed at 2 m height from the ground level for capturing the optimum fruit flies and highly recommended to control fruit fly males in the Jujube orchard. Further study is much needed to observe the different heights of traps based on various distance against different species of fruit flies.

6. CONFLICT OF INTEREST

The authors declared no conflict of interest.

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