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Comparative Efficacy of Different Insecticides Against Cucurbit Fruit Fly *(Bactrocera cucurbitae)* on Bottle Gourd *(Lagenaria siceraria)* in Sarlahi District, Nepal

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Abstract: The present investigation was conducted to evaluate the comparative efficacy of different Insecticides against cucurbit fruit fly, *Bactrocera cucurbitae* in Bottle Gourd laid out at farmer's field in Sarlahi district. The research was designed under RCBD with 6 treatments (T1 = Spinosad @ 200ml/ha, T2 = Dichlorovos 76% EC @2ml/litre water, T3 = Lambda cyhalothrin 5% EC @ 1-2 ml/litre water, T4 = Jholmal @10ml/ litre water, T5 = Multineem (Azadirachtin 0.03%) @ 10ml/ litre water and T6 = Control (water spray) and 3 replications accommodating 12 plants in each plot. The insecticides were applied as first, second, and third sprays at pre-set, post-set, and harvest stage of Bottle Gourd in 10 days intervals between each spray and data collection being done on 3^{rd}, 7^{th}, and 10^{th} day after each spray. The results showed significant variation for studied traits. The maximum number of fruit fly per plant was 8.40 (10DAS-III) during the experiment. Cucurbit fruit flies preferred young fruits and flowers for oviposition and the results obtained high pre-set damage of 43.85% (10DAS-I) and post-set damage of 68.14% (10DAS-II). The highest fruit infestation was 52.41% & 53.71% based on number and weight respectively under control treatment. Under Spinosad treatment, the lowest insect population (1.33 at 3DAS-III) was obtained with least pre-set damage, post-set damage, and minimum fruit infestation of the insect by number (27.29%) and weight (25.90%) followed by Dichlorovos and Lambda-cyhalothrin for similar traits. While, Jholmal and Azadirachtin were inferior in controlling the fruit fly population and reducing the infestation at pre-set, post-set, and harvest stage. However, Azadirachtin and Lambda-cyhalothrin were on par in terms of post-set damage (46.32% and 47.50%), respectively. The results revealed that Spinosad is the best bio-pesticide against Cucurbit fruit fly in Bottle Gourd with Dichlorovos and Lambda-cyhalothrin next in order while Jholmal and Azadirachtin offered a better quality of fruits and higher yield in Bottle Gourd. While chemical insecticides may seem effective for short term, we must opt to use eco-friendly pesticides/botanicals such as Spinosad, Jholmal and Azadirachtin for pest management and thus further study is required to explore the comparative efficacy of bio-pesticides/botanicals against chemical insecticides for fruit fly management in Bottle Gourd.

Keywords: Cucurbit Fruit Fly, *Bactrocera cucurbitae*, Spinosad, Insecticides, Jholmal

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1. Introduction

Bottle Gourd (*Lagenaria siceraria*) also known as long melon, New Guinea bean and "Lauka" in Nepali are annual trailings or climbing vines in the family *Cucurbitaceae*, primarily grown for their fruits and mostly consumed as vegetables. It is commonly cultivated in tropical and subtropical areas of the world and believed to be originated from India and spread to Asia, Africa and Europe [1]. In Nepal, It is extensively cultivated in Sarlahi district (950 ha) followed by Saptari (805 ha) and Dhanusha (707 ha) [2]. Bottle Gourds including other cucurbits are extremely prone to insects and diseases which is a severe obstacle for optimum economic production. Cucurbits are however rendered inedible and unfit for consumption due to pests and diseases.

The Cucurbit fruit fly, *Bactrocera cucurbitae* is found to infest about 16 several crops of the Cucurbitaceae family [3]. It seriously limits the production and productivity of cucurbit vegetable crops and the extent of losses due to fruit fly can go from 30% to 100% depending upon the season and varieties of the cucurbits grown [4]. About 40% of fruit fly infestation was found in bitter gourd and 21% in Bottle Gourd with an average of 12.8% to 25.55% infestation in several cucurbits [3]. Screening of 13 several cucurbitaceous vegetables for two seasons revealed that Bottle gourd was the most preferred host of *B. cucurbitae* after Bitter gourd [5]. The major limiting factor in obtaining good quality fruits and high yield in cucurbits is contributed to the melon fruit fly damage [6, 7].

Different management practices are being practiced to control this pest and prevent the potential losses but three stages of its life cycle are hidden and the only adult stage is visible which has confined the control measures adopted against this pest [8]. Farmers still heavily rely on random chemical insecticides to control the fruit fly damage in Bottle Gourd and other cucurbits.

The use of insecticides like Abamectin 0.0025% resulted in only 19.35% infestation of fruit fly in sponge gourd [9] while mechanical control with a spray of Rogor was found to be the best treatment in reducing Fruit fly infestation of Bottle Gourd [10]. Sprays of Spinosad (200ml/ha) followed by a spray of Azadirachtin resulted in a minimum fruit infestation of 8.28% [11]. Dichlorovos @ 0.05%, Lambda-cyhalothrin 0.005% and Malathion @ 0.1% were found to be most effective against fruit fly respectively [1]. Similarly, botanical pesticides “Jholmal” also proved to be effective to reduce Fruit fly infestation with superior size and quality in Squash [12]. At the same time, 7.6% fruit infestation was found under the treatment of Neem Seed Kernel Extract (NSKE) (0.5%) [15]. Hence, chemical insecticides and botanicals/bio-pesticides have been proved to be an effective and most economical measure to control the Fruit fly in field condition and the effectiveness can be further improved when adopted under the Integrated Pest Management strategy (IPM).

However, it is well known that chemical insecticides are detrimental to other beneficial insects, environment, and human health and may lead to pest resurgence and resistance as well [13]. Therefore, this research was carried out to compare the efficacy of different insecticides against Cucurbit fruit fly (*Bactrocera cucurbitae)* in Bottle Gourd. The observations are primarily focused on the control of insect population and minimizing the fruit infestation at different stages (pre-set, post-set and harvest stage) aiming to lower unmarketable yield and increase the marketable yield of Bottle Gourd. This research aims to compare the efficacy of several commercially available insecticides and botanicals to control the fruit fly infestation and minimize the economic losses in Bottle Gourd.

2. Materials and Methods

2.1. Research Site

The research was conducted at the farmer’s field of Salempur (26°53’20” N latitude; 85°34’0” E longitude, 79 m above mean sea level), Sarlahi district of Nepal during Falgun-2076 to Baisakh-2077.

Salempur is one of the prospective areas soon to be included under the vegetable block in Sarlahi. The soil texture of the site was sandy loam and suitable for Bottle Gourd cultivation. The field was facilitated with proper irrigation and drainage system. It was used for cauliflower cultivation and was harvested 15 days before land preparation. The site has a tropical climatic condition with winter from Mangsir-Falgun (December-March) and summer/spring from Chaitra-Jestha (April to June).

The seedlings of Pusa Purple Summer Long (PSPL) variety of Bottle Gourd were raised in Tropical Horticulture Farm at Nawalpur, Sarlahi under protected conditions. One to two seeds per polybag were sown and covered with plastic to maintain the appropriate temperature and also to protect from insects and diseases. A regular nursery operation was carried out. The seedlings were transported from the farm to the research site at 3 leaves stage for transplantation.

2.2. Experimental Design

The research area was tilled properly by disc plow and subsequently, cross plowing was done two times with a disc harrow. The land was well labeled and the stubbles, weeds, and residues were eliminated from the field. The research was laid out in Randomized Complete Block Design (RCBD) with six treatments and three replications with a plot size of 7 m × 5 m, keeping 2m plant to plant distance and 1m plot to plot distance (Figure 1). Then seedlings of Bottle Gourd were transported from Horticulture farm at Nawalpur to the research site at three leaves stage. The experiment was carried out in 18 plots with each plot accommodating 12 plants. The seedlings were transplanted on Falgun 12, 2076 after keeping in farmer’s home by light watering for one day. While transplanting, Polybags were cut with a blade, and seedlings were carefully removed to keep the soil intact. The pits were made in each plot as per the layout and the seedlings were placed carefully (single seedlings per plot). Few seedlings were replanted as a replacement instead of damaged seedlings. From each plot 5 plants were randomly tagged for observation during the research period.

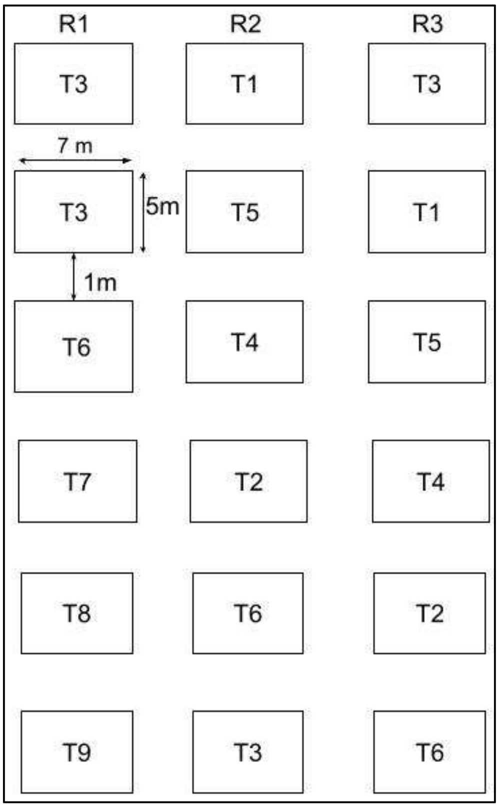

***Figure 1.** Experimental Design and Research Layout.*

2.3. Treatment Application

Five different insecticides (chemical insecticides and bio-pesticides) available at agro-vet centers were selected for the research. The study was carried out with six different treatments including control.

T1 = Spinosad (Trade name: Tracer) 0.016% 45 SC @ 200ml/ha

T2 = Dichlorovos (Trade name: Nuvan) 76% EC @2ml/litre water

T3 = Lambda cyhalothrin (Trade name: Santri) 5% EC @ 1-2 ml/litre water

T4 = Jholmal @10ml/ litre water

T5 = Multineem (Neem oil based EC containing Azadirachtin 0.03%) @ 10ml/ litre water

T6 = Control (water spray)

The insecticides were applied in assigned plots as per the dosage of the treatments with the help of a Knapsack sprayer (10ltr). The sprayer was rinsed properly with water before and after each spraying to prevent the mixing of the insecticides. Spraying was done in the afternoon with caution to avoid the insecticides from drifting to the adjacent plots. For control treatment (T6), water was sprayed so that the impact of the spraying effect could be similar in all treatments. All the treatments were applied three times at 10 days intervals coinciding with the three main stages of Bottle Gourd development.

First spray = Flowering stage (Pre-set stage)

Second spray = Post-set stage (<100 gm)

Third spray = Harvest stage (Horticultural Maturity)

The treatments were applied after the insect population was visibly prominent during the flowering stage. Ample spacing was maintained between the plots to avoid cross-contamination of insecticides by drifting.

2.4. Observations Recorded

The experiment was monitored closely at regular intervals. The data were recorded at 3rd, 7th and 10th day intervals after each spray by selecting and tagging five plants randomly from each plot. The observations were recorded for the traits mentioned in Table 1.

***Table 1.** Data collected during the Research Period.*

Observations	Stage of Bottle Gourd
Number of female fruit fly	Pre-set, Post-set and Harvest stage
Number of male and female flowers (Ovary) & Sex ratio	Pre-set stage (Flowering stage)
Number of damaged female flowers (Ovary) by fruit fly (Pre-set damage)	Pre-set stage (Flowering stage)
Total number of Post-set fruits and the number of damaged Post-set fruits	Post-set stage
Length, Girth, and weight of single fruit	Harvest stage
Total damaged fruits (number and weight basis) at marketable size	Harvest stage
Total harvested fruits (number and weight) at marketable size	Harvest stage

2.5. Calculations

2.5.1. Percentage of Pre-set Damage (Ovary Damage)

The damaged ovaries present on each vine and ground were recorded along with healthy ovaries on each vine. The data of pre-set damage was recorded on the 3rd, 7th, and 10th day after the first spray and the percentage of damage in the ovary was calculated on number basis by using the following formula given by [1, 14].

$$\text{Ovary Infestation (\%)} = \frac{Number\ of\ damaged\ Ovary}{Total\ number\ of\ Ovary} \times 100\%$$

2.5.2. Percentage of Post-set Damage Fruits

The fruits just set and less than 100 gm weight were recorded as post-set fruits. The total number of post-set fruits was counted along with the number of damaged post-set fruits. Observations were recorded on the 3rd, 7th, and 10th day after the second spray. The percentage of post-set damage fruits were calculated by using the following formula given by [1, 14].

$$\text{Post-set damage (\%)} = \frac{No.\ of\ damaged\ post-set\ fruits}{Total\ no.\ of\ post-set\ fruits} \times 100\%$$

2.5.3. Percentage of Fruit Infestation (Harvest Damage)

Fruits of the Bottle Gourd were manually harvested when marketable size was attained. Each fruit from every plot was examined properly to categorize as marketable and unmarketable. The weights of marketable and unmarketable Bottle Gourds from each plot were recorded from a single harvest and the percent infestation was calculated (number and weight basis) by using the formula given by [1, 14].

Fruit Infestation (%)

$$\text{(Number basis)} = \frac{Number\ of\ Unmarketable\ fruits}{Total\ number\ of\ fruits} \times 100\%$$

$$\text{(Weight basis)} = \frac{Weight\ of\ Unmarketable\ fruits}{Total\ weight\ of\ fruits} \times 100\%$$

2.6. Statistical Analysis

The obtained data were entered in Microsoft Excel and imported in R-Studio for data analysis. The Analysis of Variance (ANOVA) was performed for the number of male and female flowers per plant, days to flowering, number of cucurbit fruit fly per plant, number of fruits infested at pre-set, post-set and harvest stage respectively. Similarly, the ANOVA was performed for fruit infestation at the harvest stage on number and weight basis as well as the length, girth and weight of the fruits. All the data were subjected to Normality Test to confirm whether they met ANOVA assumption before analysis. The mean performance was analyzed and the significance of the difference among the treatment means was calculated by the Least Significant Difference (LSD) test at a 5% level of significance.

3. Results

3.1. Analysis of Variance

The Analysis of variance showed that all of the studied traits were significantly different for treatments except the number of male and female flowers per plant, the total number of flowers per plant, sex-ratio per plant, and the number of post-set fruits/plant. However, replication does not show significant variation for all studied traits except the fruit fly population/plant at 7DAS-III.

3.2. Number of Male & Female Flower Per Plant and Sex-ratio

The treatments had a non-significant effect on the number of male and female flowers per plant in Bottle Gourd. The number of female flowers per plant was ranged from 7 (3DAS-I) to 17 (10DAS-I). While, average female flowers per plant were 7.38, 11.11, and 15.66 on the third, seventh, and tenth day after the first spray of insecticides, respectively (Table 2). In the case of male flower it ranged from 38.00 (3DAS-I) to 79.80 (10DAS-I) with an average of 39.49, 56.89, and 76.52 on 3DAS-I, 7DAS-I, and 10DAS-I, respectively. The average sex- ratio (male: female) per plant observed from the experiment was 5.50 (3DAS-I), 5.2 (7DAS-I), and 4.92 (10DAS-I) (Table 2).

3.3. Fruit Fly Population Per Plant

The mean population of cucurbit fruit fly per plant in Bottle Gourd was recorded highest under control condition at 10DAS-III (8.40) followed by 10DAS-II (7.27) and 7DAS-III (7.00). Fruit fly population was recorded lowest under Spinosad followed by Dichlorovos and Lambda Cyhalothrin at all intervals and stages of insecticide spray i.e. 3DAS-I (1.87, 1.93 &1.87), 7DAS-I (1.87, 2.07 & 2.4), 10DAS-I (2.93, 3.2 & 3.27), 3DAS-II (1.47, 1.8 & 2.07), 7DAS-II (2.13, 2.6 & 3.2), 10DAS-II (2.73, 3.47 & 3.6), 3DAS-III (1.33, 2.00 & 2.53), 7DAS-III (2.2, 2.8 & 3.47) and 10DAS-III (3.4, 4.07 & 4.80) respectively (Table 3). The observation showed that Azadirachtin and Jholmal treatment had a higher fruit fly population as compared to other insecticides. The coefficient of variation for the fruit fly population at different intervals and stages were ranged from 4.38 (7DAS-III) to 12.32 (3DAS-I) (Table 3).

3.4. Pre-set and Post-set Damage

3.4.1. Pre-set Damage

The percentage of pre-set damage was recorded lowest under Spinosad, Dichlorovos and Lambda-cyhalothrin at all intervals after first spray i.e. 3DAS-I (16.67%, 23.57% & 23.57%), 7DAS-I (21.97%, 26.92% & 26.92%) and 10DAS-I (22.96%, 28.88% & 31.17%), respectively (Table 4 and Figure 2). While, highest damage was observed under control treatment as 43.85% (10DAS-I) followed by 41.57% (7DAS-I) and 40.74% (3DAS-I).. Under Azadirachtin and Jholmal, the pre-set damage% was 29.98% & 29.45% (3DAS-I), 32.76% & 32.75% (7DAS-I) and 27.05% & 21.98% (10DAS-I), respectively. The coefficient of variation for percentage of pre-set damage ranged from 5.65 (10DAS-I) to 11.60 (3DAS-I). At the same time, pre-set damage reduction over control was highest under Spinosad i.e., 59.08% (3DAS-I), 47.15% (7DAS-I), and 47.64% (10DAS-I) followed by Dichlorovos and Lambda Cyhalothrin at 3DAS-I (42.15% & 38.07%), 7DAS-I (35.24% & 26.20%), and10DAS-I (34.14% & 28.91%), respectively. Azadirachtin and Jholmal showed lower reduction in terms of pre-set damage at different intervals as compared to other insecticides at 3DAS-I (27.71% & 26.41%), 7DAS-I (21.21% & 21.19%), and 10DAS-I (21.98% & 27.05%) respectively (Table 4).

3.4.2. Post-set Damage

The treatment of Spinosad, Dichlorovos and Lambda-cyhalothrin recorded lowest post-set damage percentage at different intervals after second spray i.e. 3DAS-II (26.83%, 35.00% & 36.66%), 7DAS-II (37.40%, 46.45% & 47.50%) and 10DAS-II (40.65%, 49.62% & 52.47%), respectively. Under control condition post-set damage was highest 51.83% (3DAS-II) followed by 57.53% (7DAS-II) and 52.72% (10DAS-II). Azadirachtin and Jholmal recorded 42.46% & 39.47% (3DAS-II), 46.32% & 51.77% (7DAS-II) and 52.72% & 53.05% (10DAS-II), respectively. The coefficient of variation for percent of post-set damage ranged from 7.48 (10DAS-II) to 16.50 (3DAS-II) (Table 5 and Figure 3). While, post-set damage reduction in Spinosad, Dichlorovos, Lambda-cyhalothrin, Azadirachtin and Jholmal was significant over control at all intervals i.e. 3DAS-II (48.23%, 32.47%, 29.27%, 18.08% & 23.85%), 7DAS-II (34.99%, 19.26%, 17.43%, 19.49% & 10.01%) and 10DAS-II (40.34%, 27.18%, 23.00%, 22.63% & 22.15%) respectively (Table 5).

***Table 2.** Flowering behavior of Bottle Gourd during the crop season 2020 in Sarlahi district of Nepal.*

Days after Spray (DAS)	Female flower/plant		Male flower/plant		Total flowers /plant		Sex ratio (male: female)	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
3DAS-I	7.38	7.00- 7.80	39.49	38.00-41.00	46.88	45.2-48.40	5.50	5.19-5.91
7DAS-I	11.11	10.40-11.80	56.89	55.80-57.80	68.03	67.00-69.40	5.20	4.87-5.48
10DAS-I	15.66	14.00-16.80	76.52	72.60-79.80	92.18	86.60-95.80	4.92	4.59-5.29

3DAS-I= Third day after first spray; 7DAS-I= Seven Days after first spray; 10DAS-I= Ten days after first spray.

***Table 3.** Efficacy of different Insecticides on Distribution of Cucurbit Fruit flies (B. cucurbitae) per plant after first, a second and third spray during the crop season 2020 in Sarlahi district of Nepal.*

Dates / Treatments	T1	T2	T3	T4	T5	T6	LSD (0.05)	CV (%)	F value
The first Spray of insecticide (DAS-I) @ Pre-set stage									
3DAS-I	1.87 c	1.93 c	1.87c	2.53 b	2.47 b	3.27a	0.179	12.32	15.20 ***
7DAS-I	1.87 d	2.07 cd	2.4 c	3 b	2.93 b	4.2 a	0.192	11.11	22.47***
10DAS-I	2.93 c	3.2 c	3.27 c	4.47 b	4.33 b	5.4 a	0.149	6.23	24.52***
The second spray of insecticide (DAS-II) @ Post-set stage									
3DAS-II	1.47 d	1.8 c	2.07 c	3.00 b	2.87 b	4.2 a	0.171	10.95	49.35 ***
7DAS-II	2.13 e	2.6 d	3.2 c	3.73 b	3.6 bc	5.07a	0.140	6.66	44.58***
10DAS-II	2.73 e	3.47 d	3.6 cd	4.4 b	4.2 bc	7.27a	0.158	6.35	41.56***
The third spray of insecticide (DAS-III) @ Harvest stage									
3DAS-III	1.33 e	2.00 d	2.53 c	3.54 b	3.07 b	5.6 a	0.180	10.20	70.20***
7SAS-III	2.2 e	2.8 d	3.47 c	4.4 b	4.2 b	7.00 a	0.103	4.38	143.25***
10DAS-III	3.40 d	4.07 cd	4.80 bc	5.47 b	4.87 bc	8.40 a	0.258	9.11	13.29 ***

3DAS-I= Third day after first spray; 7DAS-I= Seven Days after first spray; 10DAS-I= Ten days after first spray, 3DAS-II= Third days after second spray; 7DAS-II= Seven days after second spray; 10DAS-II= Ten days after second spray; 3 DAS-III= Third days after third spray; 7DAS-III= Seven days after third spray; 10DAS-III= Ten days after third spray, T1= Spinosad; T2 = Dichlorovos; T3 = Lambda Cyhalothrin; T4 = Jholmal; T5 = Azadirachtin; T6 = Untreated control, Level of Significance: '***' @ 0.001% level of significance '**' @ 0.% level significance and '*' @ 0.05% level of significance.

***Table 4.** Efficacy of different Insecticides on Pre-set damage during the crop season 2020 in Sarlahi district of Nepal.*

Dates / Treatments	T1	T2	T3	T4	T5	T6	LSD	CV (%)	F value
Pre-set Damage (number per plant)									
3DAS-I	1.27 d	1.73 c	1.87 bc	2.20 b	2.20 b	2.93 a	0.45	12.57	14.43***
7DAS-I	2.47 e	2.93 d	3.33 cd	3.80 b	3.60 bc	4.60 a	0.49	8.02	21.19***
10DAS-I	3.60 d	4.47 c	4.80 c	5.47 b	5.27 b	6.53 a	0.38	4.28	63.88***
Pre-set Damage (%)									
3DAS-I	16.67 d	23.57 c	23.57 c	29.45 b	29.98 b	40.74 a	5.70	11.60	18.91***
7DAS-I	21.97 d	26.92 c	26.92 c	30.68 bc	32.76 b	41.57 a	4.18	7.56	23.43***
10DAS-I	22.96 d	28.88 c	31.17 bc	34.21 b	31.99 bc	43.85 a	3.23	5.65	43.17***
Damage reduction over control (%)									
3DAS-I	59.08	42.15	38.07	27.71	26.41	-	-	-	-
7DAS-I	47.15	35.24	26.20	21.21	21.19	-	-	-	-
10DAS-I	47.64	34.14	28.91	21.98	27.05	-	-	-	-

3DAS-I= Third day after first spray; 7DAS-I= Seven Days after first spray; 10DAS-I= Ten days after first spray, T1= Spinosad; T2 = Dichlorovos; T3 = Lambda Cyhalothrin; T4 = Jholmal; T5 = Azadirachtin; T6 = Untreated control, Level of Significance: '***' @ 0.001% level of significance '**' @ 0.% level significance and '*' @ 0.05% level of significance.

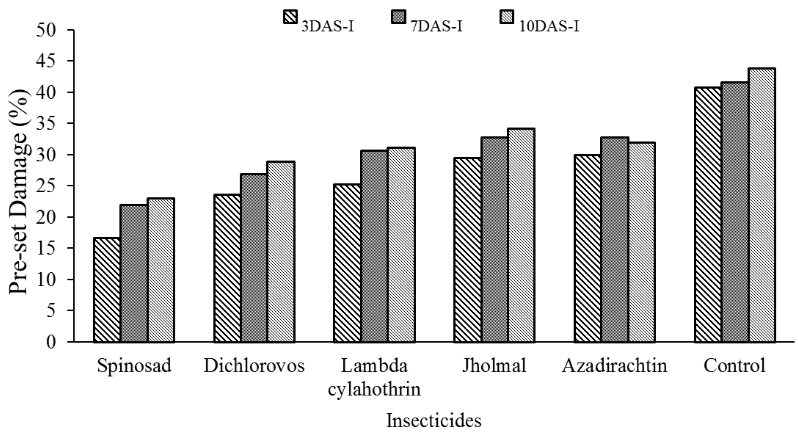

***Figure 2.** Percentage at Pre-set damage in Bottle gourd due to Cucurbit Fruit fly during the crop season 2020 in Sarlahi district of Nepal.*

***Table 5.** Efficacy of different Insecticides on Post-set damage of bottle gourd during the crop season 2020 in Sarlahi district of Nepal.*

Dates / Treatments	T1	T2	T3	T4	T5	T6	LSD	CV(%)	F value
Post-set Damage (number per plant)									
3DAS-II	3.13 c	3.80 bc	4.20 b	4.20 b	4.47 ab	5.47 a	1.03	13.70	5.36*
7DAS-II	4.07 c	4.87 b	5.00 b	5.20 b	5.00 b	6.00 a	0.80	8.89	5.79**
10DAS-II	4.13 c	4.93 b	5.20 b	5.27 b	5.20 b	6.40 a	0.62	6.74	13.02***
Post-set Damage (%)									
3DAS-II	26.83 c	35.00 bc	36.66 bc	39.47 b	42.46 ab	51.83 a	11.35	16.50	5.10*
7DAS-II	37.40 c	46.45 b	47.50 b	51.77 ab	46.32 b	57.53 a	8.77	10.31	5.50*
10DAS-II	40.65 c	49.62 b	52.47 b	53.05 b	52.72 b	68.14 a	7.02	7.48	15.14***
Damage reduction over control (%)									
3DAS-II	48.23	32.47	29.27	23.85	18.08	-	-	-	-
7DAS-II	34.99	19.26	17.43	10.01	19.49	-	-	-	-
10DAS-II	40.34	27.18	23.00	22.15	22.63	-	-	-	-

3DAS-II= Third days after second spray; 7DAS-II= Seven days after second spray; 10DAS-II= Ten days after second spray, T1= Spinosad; T2 = Dichlorovos; T3 = Lambda Cyhalothrin; T4 = Jholmal; T5 = Azadirachtin; T6 = Untreated control, Level of Significance: '***' @ 0.001% level of significance '**' @ 0.% level significance and '*' @ 0.05% level of significance.

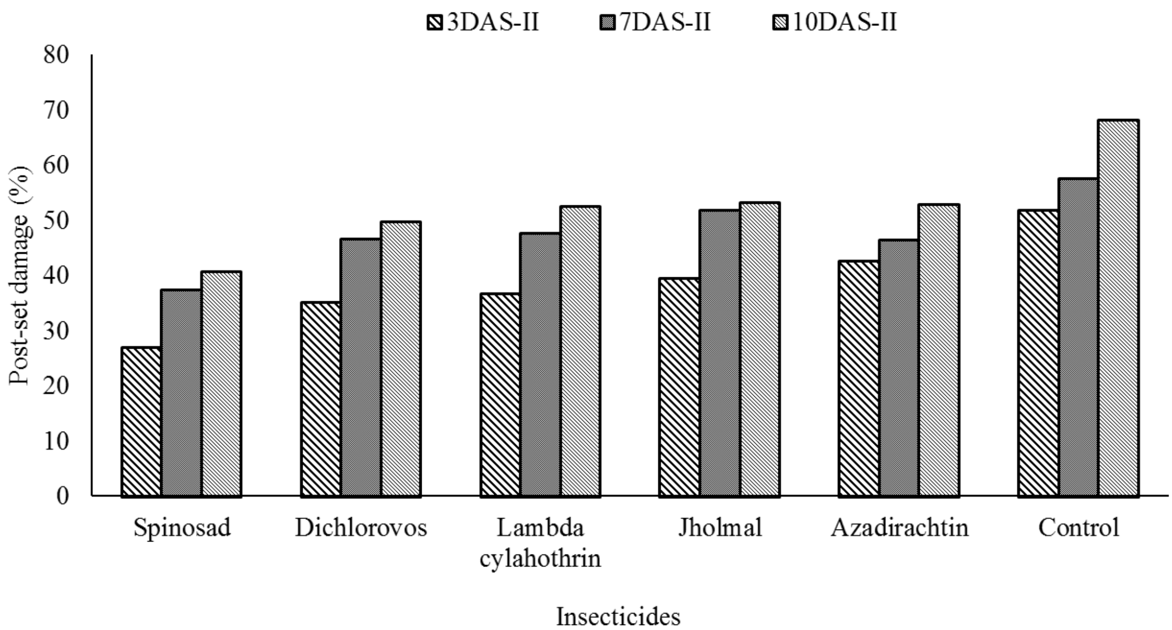

***Figure 3.** Damage Percentage at Post-set stage of bottle gourd due to Cucurbit Fruit fly during the crop season 2020 in Sarlahi district of Nepal.*

3.5. Fruit Infestation (Number Basis)

The efficacy of different insecticides in controlling fruit infestation (by number) due to Cucurbit Fruit fly after the third spray has been presented in Table 7. It is evident from the table that the total number of fruits per plant was highest in Spinosad treatment (10.27) followed by Dichlorovos (9.73). However, Lambda-cyhalothrin (9.47), Jholmal (9.47), and Azadirachtin (9.33) were on par with each other. The minimum number of fruits was obtained from control plots (8.80). The coefficient of variation for the total number of fruits per plant was 4.697. However, the number of unmarketable fruits per plant was lowest under Spinosad spray followed by Dichlorovos, Lambda-cyhalothrin, and Dichlorovos with 2.80, 2.87, and 3.27 unmarketable fruits per plant, respectively. Similarly, a higher number of unmarketable fruits were recorded under Jholmal (3.6) and Azadirachtin (3.6) (Table 8). Under control treatment, the highest number of unmarketable fruits (4.60) had been recorded. The coefficient of variation for the number of unmarketable fruits per plant was 10.50.

The number of marketable fruits per plant was recorded high under Spinosad sprayed plots (7.47) followed by Dichlorovos (6.87), Lambda-cyhalothrin (6.20). Jholmal (5.80) and Azadirachtin (5.67) had a lower number of marketable fruits while the lowest number of marketable fruits (4.20) was obtained in control plots. The coefficient of variation for the number of marketable fruits per plant was 9.14. In the case of percent of fruit infestation based on the number, the highest fruit infestation was recorded under the control plot (52.41%).

The lowest fruit infestation was found in Spinosad treatment (27.29%) followed by Dichlorovos (29.54%) and Lambda-cyhalothrin (34.49%). While, Jholmal and Azadirachtin showed 38.56% & 38.04% fruit infestation, respectively (Table 8). The coefficient of variation for fruit infestation% was 10.78. Considering the reduction in infestation, Spinosad was able to reduce 47.93% of fruit infestation per plant over control. Similarly, Dichlorovos, Lambda-cyhalothrin, Jholmal, and Azadirachtin were able to reduce the infestation by 43.64%, 34.20%, 26.43%, and 27.42% over control respectively (Table 8).

3.6. Fruit Infestation (Weight Basis)

The consequences of different treatments in controlling fruit infestation due to cucurbit Fruit fly in Bottle Gourd based on fruit weight (kg) has been presented in Table 7. The maximum total fruit weight (kg) per plant was harvested from Spinosad (14.27) followed by Jholmal (14.00) and Dichlorovos (13.47) treated plants. The total weight of fruits harvested was least (10.85) in the control treatment. While, under Azadirachtin and Lambda-cyhalothrin treated plots total fruit weight per plant was 12.80 kg and 11.93kg, respectively (Table 7). The coefficient of variation for the total weight of fruits per plant was 6.071.

In terms of unmarketable fruits, the lowest damaged fruits based on the weight had been recorded in Spinosad (3.74) and Dichlorovos (3.77) treated plots. While the weight of unmarketable fruits harvested per plant was highest (5.83) under control treatment. The treatment of Lambda-cyhalothrin, Azadirachtin, and Jholmal produced 4.18, 4.68, and 5.22 kg unmarketable fruits, respectively (Table 8). The coefficient of variation for the unmarketable weight of fruits per plant was 15.90. However, the weight of marketable fruits was highest under Spinosad treatment (10.53) and lowest (5.02) in the control treatment. Treatments Dichlorovos, Jholmal, Azadirachtin, and Lambda-cyhalothrin had marketable fruits as 9.70, 8.783, 8.12, and 7.75 kg, respectively. The coefficient of variation for the marketable weight of fruits per plant was 7.044.

The percentage of fruit infestation on a weight basis was ranged from 25.90% (Spinosad treatment) to 53.71% control plots. Under Dichlorovos, Lambda-cyhalothrin, Jholmal, and Azadirachtin treatments 28.00%, 34.96%, 37.31%, and 36.57% fruit infestation, respectively (Table 8). At the same time, Spinosad, Dichlorovos, Lambda-cyhalothrin, Jholmal, and Azadirachtin were able to reduce the fruit infestation by 51.78%, 47.87%, 34.91%, 30.53%, and 32.91% respectively. The coefficient of variation for the percentage of fruit infestation per plant was 12.034.

3.7. Girth and Length of Fruit

The impact of several insecticides on the girth of marketable fruits has been presented in Table 6. The results obtained from the measurement showed that the highest girth of fruit was 29.00 cm in Jholmal followed by 25.67 cm in Spinosad, Azadirachtin (24.33 cm), Dichlorovos (21.67 cm), and Lambda-cyhalothrin (20.67 cm) while the lowest girth of single fruit was 16.33 cm obtained in control plots. The coefficient of variation for the girth of fruit was 11.631.

Significant variations were observed among the treatments in terms of length of marketable fruits. The effect of different insecticides on the length of marketable fruits of Bottle Gourd has been presented in Table 6. The highest length of single fruit (49 cm) was recorded in Jholmal which was statistically on par with 47.00 cm in Spinosad treatment followed by 46.00 cm in Azadirachtin, 41.33 cm in Dichlorovos and 37.33 cm in Lambda-cyhalothrin. On the other hand, the lowest length of single fruit obtained from marketable fruits was 33.00 cm in the control treatment. The coefficient of variation for the length of fruit was 6.905.

Table 6. *Effect of different Insecticides on Yield contributing characters of Bottle gourd during the crop season 2020 in Sarlahi district of Nepal.*

Treatments	Length of single fruit(cm)	The girth of single fruit (cm)
T1	47.00 a	25.67 ab
T2	41.33 bc	21.67 bc
T3	37.33 cd	20.67 cd
T4	49.00 a	29.00 a
T5	46.00 ab	24.33 abc
T6	33.00 d	16.33 d
LSD (0.05)	5.19	4.75
CV	6.90	11.63
F value	13.57 ***	8.13 **

T1= Spinosad; T2 = Dichlorovos; T3 = Lambda Cyhalothrin; T4 = Jholmal; T5 = Azadirachtin; T6 = Untreated control, Level of Significance: '***' @ 0.001 per cent level of significance '**' @ 0.01 per cent level significance and '*' @ 0.05 per cent level of significance.

3.8. Yield of Bottle Gourd

The unmarketable fruit yield was highest (19.98 mt/ha) in control plots and lowest in Spinosad (12.83 mt/ha). The treatments Dichlorovos, Lambda-cyhalothrin, Azadirachtin, and Jholmal recorded 12.93 mt/ha, 14.33 mt/ha, 16.06 mt/ha, and 17.90 mt/ha unmarketable yield, respectively. In terms of percent decrease of unmarketable yield over control, Spinosad had the highest decrement of 55.72% followed by 54.52% in Dichlorovos, 39.42% in Lambda-cyhalothrin, 19.62% in Azadirachtin and 11.62% in Jholmal. The coefficient of variation for the total unmarketable yield of Bottle Gourd was 15.896. While, The highest marketable yield (mt/ha) was obtained from Spinosad treatment (36.11 mt/ha) followed by Dichlorovos (33.25 mt/ha), and Jholmal (30.11 mt/ha). Control plots had the lowest marketable yield of 17.21 mt/ha. Under Azadirachtin and Lambda-cyhalothrin marketable yield was 27.84 mt/ha and 26.57 mt/ha, respectively. The percent increase over control with regards to marketable yield was highest in Spinosad spray (52.34%). Dichlorovos showed a 48.24% increase in marketable yield over control while it was 35.22% in Lambda-cyhalothrin, 42.84% in Jholmal, and 38.18% in Azadirachtin. The coefficient of variation for the total marketable yield of Bottle Gourd was 7.043. The descending order of comparative efficacy of several insecticides based on marketable fruit yield was Spinosad > Dichlorovos > Jholmal > Azadirachtin > Lambda-cyhalothrin (Table 7).

***Table 7.** Comparative Efficacy of different Insecticides on Yield of Bottle gourd during the crop season 2020 in Sarlahi district of Nepal.*

Treatments	Unmarketable yield (mt/ha)	Decrease over control (%)	Marketable yield (mt/ha)	Increase over control (%)
T1	12.83 c	55.72	36.11 a	52.34
T2	12.93 c	54.52	33.25 ab	48.24
T3	14.33 bc	39.42	26.57 c	35.22
T4	17.90 ab	11.62	35.22 a	42.84
T5	16.06 abc	19.62	27.84 c	38.18
T6	19.98 a	-	17.21 d	-
LSD (0.05)	4.43	-	3.57	-
CV	15.90	-	7.04	-
F value	3.97 *	-	31.93***	-

T1= Spinosad; T2 = Dichlorovos; T3 = Lambda Cyhalothrin; T4 = Jholmal; T5 = Azadirachtin; T6 = Untreated control, Level of Significance: '***' @ 0.001 per cent level of significance '**' @ 0.01 per cent level significance and '*' @ 0.05 per cent level of significance.

***Table 8.** Comparative Efficacy of different Insecticides on fruit infestation of Bottle gourd due to Cucurbit Fruit fly (number and weight basis) during the crop season 2020 in Sarlahi district of Nepal.*

Treatments	Number basis					Weight basis (kg/plant)				
	Total fruits	Unmarketable fruits	Marketable fruits	Damage %	Reduction over control (%)	Total fruits	Unmarketable fruits	Marketable fruits	Damage %	Reduction over control (%)
T1	10.27 a	2.80 c	7.47 a	27.29 d	47.93	14.27 a	3.74 c	10.53 a	25.90 d	51.78
T2	9.73 ab	2.87 c	6.87 ab	29.54 cd	43.64	13.47 a	3.77 c	9.70 ab	28.00 cd	47.87
T3	9.47 bc	3.27 bc	6.20 bc	34.49 bc	34.20	11.93 bc	4.18 bc	7.75 c	34.96 bc	34.91
T4	9.47 bc	3.60 b	5.80 c	38.56 b	26.43	14.00 a	5.22 ab	8.78 bc	37.31 b	30.53
T5	9.33 bc	3.60 b	5.67 c	38.04 b	27.42	12.80 ab	4.68 abc	8.12 c	36.57 b	31.91
T6	8.80 c	4.60 a	4.20 d	52.41 a	-	10.85 c	5.83 a	5.02 d	53.71 a	-
LSD (0.05)	0.79	0.65	0.98	7.04	-	1.54	1.29	1.04	7.72	-
CV	4.70	10.50	9.14	10.78	-	6.70	15.90	7.04	12.03	-
F value	3.49*	9.87**	12.49***	15.19***	-	6.92**	3.97*	31.93***	15.36***	-

T1= Spinosad; T2 = Dichlorovos; T3 = Lambda Cyhalothrin; T4 = Jholmal; T5 = Azadirachtin; T6 = Untreated control, Level of Significance: '***' @ 0.001 per cent level of significance '**' @ 0.01 per cent level significance and '*' @ 0.05 per cent level of significance.

3.9. Relationship Between Fruit Infestation (%) (by Number and Weight) Due to Cucurbit Fruit Fly and Marketable Yield in Bottle Gourd Among Different Insecticides

In Figure 4, the linear regression among different insecticides has been showed the relationship between the percent of fruit infestation/plant (number basis) and Marketable yield of Bottle Gourd. The equation y = -0.6497x + 52.375 gave a good fit to the data and the coefficient of determination (r^2) was 0.8337 i.e. r = -0.913 which showed a highly significant association between the parameters (Figure 4). The results indicated that marketable fruit yield (mt/ha) was decreased due to an increase in the percentage of fruit infestation per plant (by number) due to cucurbit Fruit fly in Bottle Gourd.

In Figure 5, the relationship between the percent of fruit infestation/plant (weight basis) and Marketable yield of Bottle Gourd was established by conducting a linear correlation study among different insecticides. The equation y = -0.5979x + 50.084 gave a good fit to the data and the coefficient of determination (r^2) was 0.8546 i.e. r = -0.924 which showed a highly significant relationship between the studied parameters (Figure 5). The result showed that marketable fruit yield (mt/ha) was decreased due to an increase in the percentage of fruit infestation per plant due to cucurbit Fruit fly in Bottle Gourd.

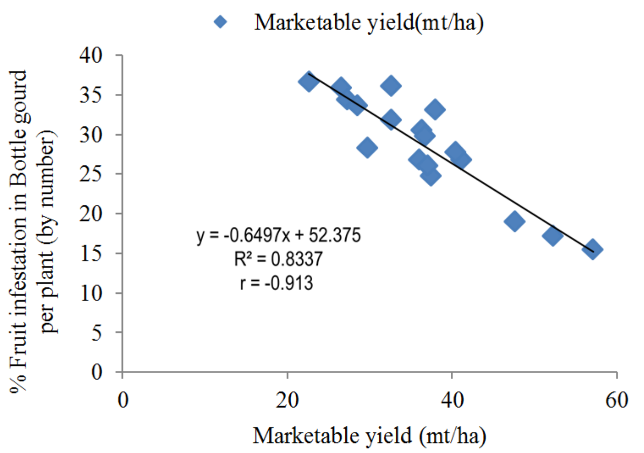

***Figure 4.** Relationship between Fruit infestation (%) due to Cucurbit fly (by number) and Marketable yield in bottle gourd among different Insecticides.*

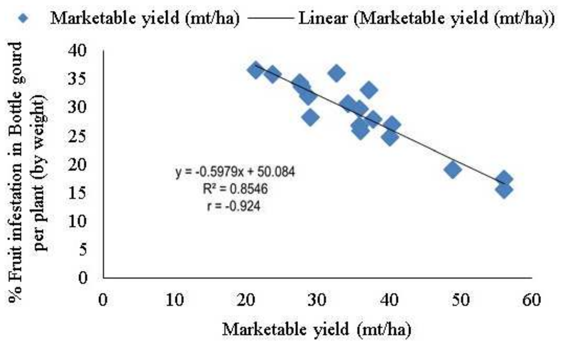

Figure 5. *Relationship between Fruit infestation (%) due to Cucurbit fruit fly (by weight) and Marketable yield in bottle gourd among different Insecticides.*

4. Discussion

The present investigation was conducted entitled "Comparative Efficacy of Different Insecticides against Cucurbit fruit fly *(Bactrocera cucurbitae)* on Bottle Gourd *(Lagenaria siceraria)* in Sarlahi District, Nepal". The Analysis of variance was significant for all the parameters observed during the study except the number of male and female flowers per plant, the total number of flowers per plant, sex-ratio per plant, number of ovaries and post-set fruits setting per plant. These results depict that the pesticides lack the element promoting flowering in bottle gourd. The results obtained from ANOVA also indicated that the treatment used in the present investigation has different levels of efficacy to control the infestation of the fruit fly. In the present investigation, the effect of replication was found non-significant except for the fruit fly population/plant at 7DAS-III indicated that the experiment was conducted properly.

The results obtained from the current research revealed the effect of fruit fly infestation in the yield of bottle gourd and the efficacy of the insecticides (Spinosad, Dichlorovos, Lambda-cyhalothrin, Azadirachtin and Jholmal) was also assessed. The linear regression obtained between the percent of Fruit infestation (by number and weight) and the Yield of Bottle Gourd. Fruit infestation (%) by number and weight were negatively associated with the yield of Bottle Gourd. Previous studies also suggested that cucurbit fruit fly infestation led to potential yield loss in Bottle Gourd. Yield loss of 30%-100% was observed duet to cucurbit fruit fly in cucurbits [4] and fruit fly damage was regarded as the major limiting factor in obtaining high yield in cucurbits [6, 7]. Similarly, the percentage of yield loss due to cucurbit fruit flies may differ from 30 to 100% according to the type of cucurbit crops and season in which they are cultivated [4]. Results of screening 13 several cucurbitaceous vegetables for two seasons and revealed that Bottle Gourd was the most preferred host of *B. cucurbitae* after Bitter gourd [5]. The major limiting factor in obtaining good quality fruits and high yield in cucurbits was contributed to the melon Fruit fly damage [6, 7]. Similarly, Cucurbit fruit fly caused about 33.39% damage to cucumber during harvesting and 37.6% fruit infestation was observed due to cucurbit fruit fly in Squash [8 and 12]. The current study recorded 38.18% to 52.34% yield loss in control plots due to cucurbit fruit fly. This result is slightly similar to the yield loss of 27.3% to 49.3% due to fruit fly in Bottle Gourd [15].

The Chemical insecticides and Botanicals/Bio-pesticides used in this study had a significant effect on the traits observed in Bottle Gourd. The efficacy of insecticides (Spinosad, Dichlorovos, Lambda-cyhalothrin, Jholmal, and Azadirachtin) on fruit fly population, pre-set damage, post-set damage, and harvest damage (Fruit infestation) was recorded after the first, second and third spray of the treatments.

Spinosad had recorded the least mean population of 2.22, 2.11, and 2.31 insects per plant after first, second and third spray, respectively. Spinosad was followed by Dichlorovos (2.40, 2.62, and 2.95), Lambda-cyhalothrin (2.51, 2.6, and 3.6), Azadirachtin (3.24, 3.56, and 4.047) and Jholmal (3.33, 3.71, and 4.47) in terms of number of insects per plant in Bottle Gourd. Similarly, the observation also revealed that the mean insect population increased over time and despite using pesticides their number is in increasing trend. This may be due to their increment in tolerance and resistance gained during their development from pre-mature to mature stage. However, the insecticides were able to control the insect population effectively as compared to control.

In terms of pre-set and post-set damage, Spinosad treated plots had lowest average pre-set damage (20.53%) and post-set damage (34.96%) and it was followed by Dichlorovos and Lambda-cyhalothrin. Whereas, Spinosad had lowest fruit infestation of lowest fruit infestation of 27.29% (by number) & 25.90% (by weight) and fruit infestation was reduced by 47.93% (by number) & 51.78% (by weight) compared to control. Similar to the findings of this research, Spinosad was found to be the most effective pesticide with the lowest fruit infestation in bitter gourd when tested among several pesticides [16]. The current result is slightly similar to previous reports of 17.83%, 25.44% and 29.52% fruit damage under Spinosad treatment in Bottle Gourd, Ridge gourd and Bitter gourd respectively [17-19]. Similarly, the plots treated with Lambda-cyhalothrin showed fruit infestation of% 34.49 (by number) & 34.96% (by weight) which is slightly different with earlier observation of 25.52% fruit infestation (weight basis) in Sponge gourd in 2009 [9]. Similarly, 30.29% fruit infestation on a number basis in cucumber [1]. In case of Dichlorovos, fruit infestation of 29.54% (by number) & 28.00% (by weight) was observed which was similar to the observation of previous reports fruit infestation by 22.83% (weight), 22.65% (weight), and 39.75% (number) in Ridge gourd, Sponge gourd, and Cucumber, respectively [18, 9, 1]. From the current observations, it was revealed that Azadirachtin and Jholmal were on par with each other in terms of fruit infestation at harvest stage but Azadirachtin was slightly more effective in controlling the fruit infestation as compared to Jholmal in terms of mean insect population, pre-set and post-damage in Bottle Gourd. It was also reported that Azadirachtin was next in terms of effectiveness after Spinosad and Lambda-cyhalothrin and found to have a lower infestation which coincides with the findings of this research [17]. Similarly, neem-based products provided excellent control over *B. cucurbitae* in cucurbit production [20].

The varying fruit infestation under sprays of insecticides at different stages in Bottle Gourd in case of current research and previous findings is obvious owing to the difference in the types of crops and the location of study. However, Dichlorovos and Lambda-cyhalothrin were found on par in controlling the infestation at pre-set and post-set stage which is also supported from the findings of [1].

The fruit quality (girth and length) of Bottle Gourd was found to be highest in Jholmal treated Plots. This could be due to its positive impact owing to the nutrient-enriched supplements present in the solution for fruit growth and development. Previous studies also suggested that Jholmal application had increased the quality and yield of vegetables [21]. Jholmal was also found superior in terms of fruit size and quality and had the highest yield in spring-summer squash along than other treatments [12]. It wa also observed that Jholmal application gave superior yield in cucurbits with less Fruit fly infestation in the fruits [22].

The results of the experiment reported the highest marketable yield and lowest unmarketable yield under Spinosad and Jholmal treated plots. Dichlorovos followed them while Lambda-cyhalothrin and Azadirachtin were statistically on par with each other. The superior result of Spinosad treatment over other insecticides in terms of yield in this experiment coincides with the previous conclusions as well [11 and 23]. Similar to the findings of this research, the superior effect of Dichlorovos over Lambda-cyhalothrin was also reported in terms of fruit infestation (%) and yield in sponge gourd by [9]. This depicts the superior efficacy over several other insecticides in terms of observed traits. Previous studies and reports also advocate the superiority of Spinosad to other insecticides in fruit fly management in cucurbits.

The results from present investigation revealed better efficacy of Spinosad in terms of marketable yield, lower fruit infestation at pre-set, post-set and harvest stage, low mean insect population and better fruit quality followed by Dichlorovos and Lambda-cyhalothrin for similar traits. At the same time, Azadirachtin was found almost on par with Lambda-cyhalothrin for several traits under observation which revealed the potential of the neem based product against fruit fly in Bottle Gourd. Furthermore, although Jholmal was found to be less effective in controlling the infestation, it had promoting effect on the fruit development and thereby attaining the best fruit quality in the experiment. The results were in accordance with earlier findings and the potential of botanicals and bio-pesticides like Spinosad, Azadirachtin and Jholmal need to be explored further.

5. Conclusion

It can be inferred from the results of the present investigation that the insecticides had no effect on the flowering behavior in Bottle Gourd but caused significant variation in terms of fruit fly infestation at different stages, fruit fly population, fruit length & girth and the yield of Bottle Gourd. The fruit fly population per plant, number of damaged ovaries, percent of pre-set damage, number of post-set damage, percent of post-set damage, and percent of fruit infestation (by number and weight) was lowest under Spinosad treatment followed by Dichlorovos. Similarly, the highest marketable yield at the final harvest was obtained from Spinosad (36.11 mt/ha) and Jholmal (35.22mt//ha) followed by Dichlorovos (33.25 mt/ha), and Azadirachtin (27.84 mt/ha) and Control (17.21 mt/ha) treatment. The order of comparative efficacy of several insecticides based on marketable fruit yield was Spinosad > Dichlorovos > Jholmal > Azadirachtin > Lambda-cyhalothrin whereas, the efficacy of different insecticides in terms of fruit quality of Bottle Gourd (fruit length and girth) was in the order Jholmal > Spinosad > Azadirachtin > Dichlorovos > Lambda-cyhalothrin. Jholmal, Spinosad, and Azadirachtin showed the excellent quality of fruits (length and girth) which also suggested that botanicals/bio-pesticides possessed nutrient mineral compounds that could have promoted the fruit development in Bottle Gourd. A preliminary survey revealed the use of Dichlorovos for fruit fly management in Bottle Gourd in the research area. The use of Spinosad is least popular among commercial farmers of cucurbits probably due to their higher price as compared to other insecticides.

The scrutiny of data revealed that Spinosad is the best treatment regarding the lower prevalence of cucurbit fruit flies, reduced fruit fly infestation at different stages (pre-set, post-set and harvest stage), and yield increment in Bottle Gourd. While Dichlorovos is the next best treatment after Spinosad against fruit fly, Jholmal and Azadirachtin also possess immense potential considering their efficacy in increasing the overall yield of Bottle Gourd.

However, this research is confined to the use of few insecticides, time frames with single-season and single location which is not enough to derive a conclusive statement on the comparative efficacy of botanicals/bio-pesticide and chemical insecticides against fruit fly in Bottle Gourd. The potential effect of botanicals/bio-pesticide can be unraveled when studied under multiple seasons which have been seriously limited in current research. Nevertheless, we must keep in mind that chemical insecticides are detrimental to human health, environment, and beneficial insects and may lead to long term problems related to pest resistance and resurgence as well. Although chemical insecticides are unavoidable for short term management of cucurbit fruit fly in Bottle Gourd, we cannot neglect their negative impacts in the long run. If it is necessary to use chemical insecticides, Dichlorovos is recommended for being cheaper and easier to procure than Spinosad, Jholmal and Azadirachtin for fruit fly management in Bottle Gourd. It is also suggested to use botanicals like Jholmal and Azadirachtin for safe use and promoting the fruit quality in cucurbits. From the results of this research, Spinosad had the highest comparative efficacy against cucurbit fruit fly with higher marketable yield and is recommended to use for controlling the fruit fly infestation in Bottle Gourd.

Future studies must prioritize on exploring the potential efficacy of botanicals and bio-pesticide against *Bactrocera cucurbitae* in Bottle Gourd while decreasing the use of chemical insecticides at the same time.

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