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RESEARCH ARTICLE

SUSTAINABLE APPROACHES FOR FRUIT FLY MANAGEMENT IN BITTER GOURD CULTIVATION

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ABSTRACT

Fruit and vegetable commodities suffer significant losses in the field and after harvest due to fruit fly infestations. Adult female flies lay eggs inside mature fruits and vegetables make unfit for human consumption or marketing. A field experiment (UPA research) was conducted during the kharif season of 2022 to document the eco-friendly management of fruit flies *(Bactrocera cucurbitae)* on the bitter gourd *Momordica charantia* at Gokuleshwor, Baitadi. The experiment was laid out in a Randomized Complete Block Design (RCBD) with 7 treatments, i.e., *Bacillus thuringiensis,* Neem cake, yellow sticky trap, Chlorpyriphos 50%+ Cypermethrin 5% EC, Jhol-mol, and *Beauveria bassiana*. The treatments were replicated three times, accommodating four plants in each plot, and the variety used was a Palee F1 hybrid. The treatment was applied as a first and second spray and data collection was done on 3rd,6th,9th and 12thdays after each spray. The treatment Chlorpyriphos 50% EC + Cypermethrin 5% EC was the most effective, resulting in a minimum fruit infestation of 1.87%, followed by Bacillus *thuringiensis* 3.46%, which was at par in terms of reducing fruit infestation. Also, the number of fruit flies per plot was significantly low in Chlorpyriphos 50% EC and Cypermethrin 5% EC, i.e., 0.66, followed by *Bacillus thuringiensis*., 1.00, which were statistically at par with each other. Even though chlorpyriphos 50% and Cypermethrin 5% EC gave the best production as well as less infestation of fruit flies, they are persistence, bioaccumulation, and biomagnification in nature. So, *Bacillus thuringiensis* (Bt), which was on par with Chlorpyriphos 50% EC and Cypermethrin 5% EC, became most effective and economical for controlling the fruit flies on bitter gourd fruits that were easily available in our local market and easy to use and had no adverse effect on the environment or human health.

KEYWORDS

Fruit flies, Jhol mol, Bacillus thuringiensis, Bitter gourd

1. INTRODUCTION

Bitter gourd (*Momordica charantia)* is herbaceous, tendril- bearing climbing vine of a Cucurbitaceae family. Its origination takes place from Africa and fully domesticated in South East Asia. It is annual in temperate zone while perennial in Tropical zone. It is popular for its immature tuberculate fruits that provide unique bitter taste. It consists of slightly fuzzy stems clothed with dark green, deeply lobed leaves. Each plant consists of separate yellow male and female flower. The fruit consist of a distinct warty exterior and has an oblong shape. Its cross section is hollow with a relatively thin layer of surrounding with a central seed cavity filled of a large, flat and pith. At the mature stage, the fruit become crunchy and watery in texture. Each part of this crop has been reported as useful for some specific medicinal value(Allwood & Drew, 1997; Hollingsworth et al., 1997). A compound named 'Charantin' present in the bitter gourd which is useful to decrease the blood sugar for diabetic patients (Dhillon et al., 2005b). It is also rich in vitamins and carbohydrates. So, Bitter gourd become the most important crops. It is grown in 9680 ha with annual production of 1,37,922 Mt in Nepal (2020/21, MOALD). In Baitadi district it is cultivated in 20 ha of area with production of 161mt (MOALD, 2021). The productivity of bitter gourd is however limited due to insect pest infestation.

Insect pests play a vital role in lowering the production of bitter gourds by damaging crops. Bitter gourd is mainly attack by 24 species of insect pests at different growth stages belonging to five different orders (Rathod, 2016). The cucurbit fruit fly is the most destructive pest of bitter gourd, causing yield losses ranging from 30–100% (Dhillon et al., 2005b; Shooker et al., 2006; Sultana et al., 2017). Cucurbit fruit fly (*Bactrocera cucurbitae),* whose damage is the major limiting factor in obtaining good-quality fruit and a high yield, uses at least 125 plants as hosts; those are beans, bitter gourd, winter melon, cucumbers, eggplant, green beans, hyotan, luffa, melons, peppers, pumpkins, squashes, tomatoes, watermelon, and zucchini (Shahzadi et al., 2019; Dao et al., 2020).

The fruit fly is native to South Asia and is distribute throughout most parts of southern Asia, several countries in Africa, and some island groups in the Pacific (White, 1993). Fruit flies are mostly found near cultivated areas in low, leafy vegetation. In hot weather, they lie on the undersides of leaves, and in shady areas, they are strong fliers and usually fly in the early mornings and late afternoons. They feed on the juices of decaying fruit, nectar, bird feces, and plant sap (Manikandan et al., 2021).

The fruit fly completes its life cycle in 4 stages, i.e., egg, larva, pupa, and adult. The eggs are elliptical, white, and about 2 mm long. They are usually flat on the ventral surface and more convex on the dorsal side. The larvae are cylindrical-maggot-shaped and elongated, and the anterior end narrows somewhat ventrally (Berg, 1979). The pupa is dull red or brownish yellow to dull white in colour and is about 5 to 6 mm in length (Bauer, 2013). The adult melon fly is 6 to 8 mm in length and has distinctive characteristics, including its wing pattern, its long third antennal segment, its reddish-yellow dorsum of the thorax with light yellow markings, and its yellowish head with black spots.

The infected fruit prematurely becomes yellow, hollow, and contains brown resinous juice that oozes from the punctures, which are made by flies. Punctures serve as entry points for various bacteria and fungi, and as a result of the infection, fruits start to rot and distort. Infestation results in crop losses, loss of export markets, and/or costly treatments to ensure compliance with quarantine measures imposed by importing countries (Nazir et al., 2022).

There are various methods for controlling these insect pests, including physical, chemical, cultural, and biological methods. However, chemical pesticides are used enormously despite their adverse effects (Diwakar et al., 2008). A study shows that the highest quantity of pesticides is used in vegetables, i.e., 89 percent (1.604 a.i. kg/ha), followed by cereals, cash crops, pulses, and fruits (Sharma, 2015). Farmers are using chemical pesticides at a higher rate and in a haphazard way for the management of insect pests without considering pesticide residue, pest resistance, the resurgence of pests, the destruction of beneficial insects, environmental pollution, detrimental effects on the fertility of the soil, and human health (Abang et al., 2013). IPM practices reduce the various infestations of insect pests in bitter gourds without using hazardous insecticides and their excess doses, saving the environment as well as human life (Mal et al., 2018; Neupane, 2000).

2. MATERIALS AND METHOD

2.1 Site selection and Research site

A field experiment was carried out at Gokuleshwor Agriculture and Animal Science College, Gokuleshwor, Baitadi. Research site was located at Dilasaini Rural Municipality, ward – 5, Baitadi. It lies in mid hill region on Sudurpaschim Pradesh elevation of 700m above sea level and lies between $80^0$54'94"E longitude and $29^0$68'80"N latitude. The field was down from the college near the road facing East-West direction.

2.2 Land Preparation and Fertilizer application

The experimental site was covered with grass and weeds. So, at first, we removed all the grasses and weed. After that the field was ploughed on 2078/11/20 by tiller and it was levelled with the help of spade and racker. The soil was pulverized for the proper growth and development of the bitter gourd. FYM used was 7 Doko for the preparation of the land. The recommended dosage of 200:100:100 NPK kg/ha of fertilizer was applied.

2.3 Experimental Design

The experiment was laid out in Randomized Block Design (RCBD). The experiment included Seven treatment in three Replication. The Plot size of each treatment was 2m × 2m ($4m^2$). The distance maintained between two plots was 0.5m and each replication was separated by 1m. The total area of field was 144(18 × 8) m^2.

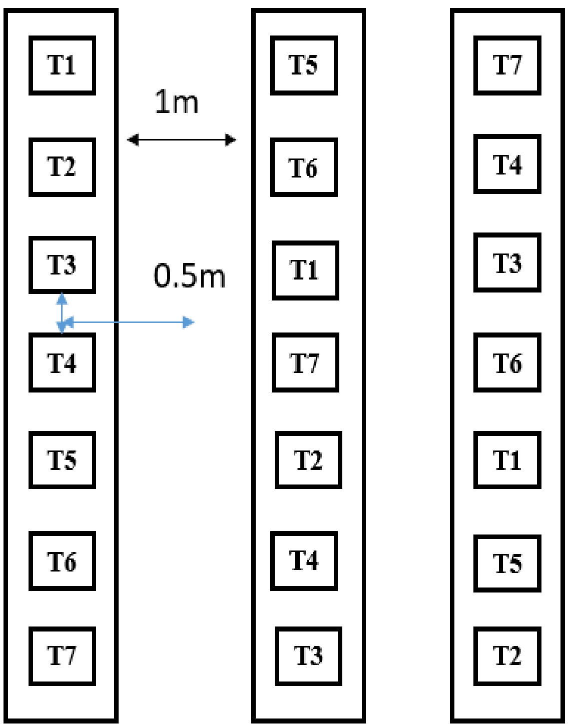

Figure 1: Experimental Design

2.4 Treatment combination

Treatment	Treatment used	Mode of Action	Dose
T1	Bacillus thuringiensis (Bt)	Protein Toxin	2ml/ ltr of water
T2	Neem cake	Anti- Feedant	5ml/ltr of water
T3	Yellow sticky trap	Adhesion	2 per plot
T4	Chloropyrifos 50% EC +Cypermethrin 5% EC	Systematic+ Contact	2ml/ltr of water
T5	Jhol-mol	Repellent	1:5 of water
T6	Beauveria bassiana	Parasitism	2gm/ltr of water
T7	Control		

2.5 Planting materials and intercultural operations

Seed were used as a planting material for bitter gourd. Palee F1 hybrid variety was used for our research because of the maximum farmer used this variety, but also the problematic by fruit fly infestation. Initially Nursery bed was built in horticulture field in 2078/12/20. The two seeds were placed per planting distance in nursery. About 100 seeds were sown in nursery bed. The Germination days were 7 days. After 27 days, they were ready to transplant and we transplanted the seedling of bitter gourd on 2079/01/17. In each plot 4 seedlings were transplanted in 1m from plant to plant. Regular irrigation was given to the field up to 7 days. Again, gap filling was done on 2079/02/07.

For ensuring proper growth and development intercultural operation like thinning out, weeding was carried out in the regular interval. Then irrigation was given at an interval of 5 days for 25 days. After that irrigation was continued according to need of plants. Weeding was done manually in every two-week time interval. Bitter gourd is a climber and they consist of vines which need support for its growth. So, after fifteen days of transplantation, a bamboo poles were used as the support for vines to promote production. Each plot four bamboo poles were placed in corner and ropes as well as bamboo poles at top were placed and tied for making them stronger.

2.6 Data collection

Observation was taken after, three days before the first spray of different treatment on plants. The number of fruit fly were counted per plant by observing the infection in fruits. Yield of infected fruits and Healthy fruit were taken from the harvest in every three days.

2.7 Data Analysis

First, the collected data were entered in excel sheet then it was analyzed with the help of R-Studio. The output of analysis presented in form of tables and figures and interpret finding with relevant literature.

3. RESULT

3.1 Number of fruit flies

The effect of application of different treatment on the number of fruit fly at different interval of subsequent spray is shown in Table 1 and Table 2. The average number of fruit fly before spray were found to be 11.57 and number of fruit fly were significantly similar among the treatments (table 1). There was a prominent ($P<0.05$) difference in the efficacy of treatments in reducing fruit flies numbers following the initial spray across all observation dates (3,6,9, and 12 Days respectively). Among the treatments Chlorpyrifos 20% EC +Cypermethrin 5% EC invariably revealed the lowest fruit fly number, proving significantly more effective than all other treatments. Chlorpyrifos 20% EC +Cypermethrin 5% EC was found to be statistically at per with Bt. Conversely, the untreated plot showed the highest fruit fly population. The highest number of fruit fly was found in untreated plot. Similar result was also obtained in second spray in which Chlorpyrifos 20% EC +Cypermethrin 5% EC was superior in suppressing the population of fruit flies in bitter gourd followed by Bt, Jholmol and Neem cake.

Table 1: Effect of treatment on number of fruit flies' population at different interval during before and after first treatment of pesticide at Gokuleshwor, Baitadi (2022/23)

		Number of fruit flies			
Treatment	**Before Spray**	**3 DAFS**	**6 DAFS**	**9 DAFS**	**12 DAFS**
Beauveria	11.33[a]	9.66[b]	8.33[bc]	8.33[ab]	8.66[ab]
Bt	11.66[a]	6.66[c]	5.33[de]	4.00[cd]	2.66[d]
Chlorpyrifos 50% EC+ Cypermethrin 5% EC	11.66[a]	4.00[c]	3.66[e]	3.66[cd]	3.00[d]
control	11.33[a]	13.66[a]	13.66[a]	11.33[a]	10.33[a]
Jhol mol	11.66[a]	6.33[c]	4.33[e]	3.33[d]	3.33[cd]
Neem cake	12.33[a]	10.00[b]	7.33[cd]	6.66[bc]	6.00[bc]
Yellow sticky trap	11.00[a]	10.66[b]	10.33[b]	9.33[ab]	10.00[a]
Grand Mean (GM)	11.57	8.71	7.57	6.66	6.28
F-test	NS	***	***	***	***
LSD (0.05)	2.40	2.67	2.36	2.88	2.81
CV (%)	11.70	17.22	17.57	24.34	25.20
SEM (±)	0.29	0.32	0.29	0.35	0.34

CV: Coefficient of Variation; LSD: Least Significant Difference; DAFS: Days After First Spray; Level of significance: *** @0.001% level of significance; ** @0.01% level of significance; *@0.05% level of significance

Table 2: Effect of treatment on number of fruit flies population at different interval during Second spray of treatment of pesticide at Gokuleshwor, Baitadi (2022/23)

	Number of Fruit flies				
Treatment	**3 DASS**	**6 DASS**	**9 DASS**	**12 DASS**	**15 DASS**
Beauveria	7.33[bc]	6.66[c]	5.00[c]	3.33[c]	3.33[bc]
Bt	2.00[d]	1.33[e]	1.33[d]	1.00[d]	1.00[c]
Chloropyrifos 20% EC +Cypermethrin 5% EC	2.33[d]	1.33[e]	1.33[d]	1.33[d]	0.66[c]
control	11.66[a]	13.00[a]	12.00[a]	11.00[a]	11.00[a]
Jhol mol	3.00[d]	3.00[de]	1.66[d]	1.66[d]	1.33[c]
Neem cake	5.33[c]	4.00[d]	3.33[cd]	2.00[cd]	1.66[c]
Yellow sticky trap	9.33[b]	8.66[b]	8.66[b]	6.33[b]	5.33[b]
Grand Mean (GM)	5.85	5.42	4.76	3.80	3.47
F-test	***	***	***	***	***
LSD (0.05)	2.13	1.98	2.75	1.45	2.59
CV (%)	20.48	20.59	32.46	21.48	41.98
SEM (±)	0.26	0.24	0.33	0.17	0.31

CV: Coefficient of Variation; LSD: Least Significant Difference; DAFS: Days After Second Spray; Level of significance: *** @0.001% level of significance; ** @0.01% level of significance; *@0.05% level of significance

3.2 % Of Fruit infestation by fruit flies

The resultant effect of different treatments on the percentage of fruit infestation caused by fruit fly on bitter gourd are presented in Table 3 and Table 4. Fruit damaged by fruit fly (%) varied from 65.87 to 77.22 before application of treatment and result found be non-significant among all the treatments (Table 4). At three days after first spray, the results showed that the highest fruit infestation was recorded in the control, which was significantly at par with Beauveria and yellow sticky trap. The lowest fruit infestation was recorded in Chlorpyrifos 50% EC + Cypermethrin 5% EC. The same result was also obtained 6 and 9 days after first spray. Twelve days after the first spray the highest fruit infestation were recorded in control whereas lowest percent of fruit infestation were recorded in Chlorpyrifos 50% EC +Cypermethrin 5% EC. Beauveria and yellow sticky trap were statistically similar with each other. Jholmol and Bt both were also statistically similar with each other. After second spray of the treatment the showed significant result at different intervals. At three days after second spray the untreated control plots had highest infestation and the Chlorpyrifos 50% EC +Cypermethrin 5% EC had the lowest infestation. Similar result was also obtained in (6,9,12 and 15 Days after second spray respectively). Chlorpyrifos 50% EC +Cypermethrin 5% EC was found to be statistically at per with Bt.

Table 3: Effect of different treatments on the percentage of fruit infestation on bitter gourd at different intervals during before and after first spray of pesticides at Gokuleshwor, Baitadi(2022/23)

Treatment	**Before spray**	**3 DAFS**	**6 DAFS**	**9 DAFS**	**12 DAFS**
Beauveria	77.22[a]	73.55[a]	68.98[a]	55.74[bc]	53.36[b]
Bt	68.15[ab]	56.03[bc]	50.41[b]	42.56[cd]	24.47[d]
Chlorpyrifos 50% EC +Cypermethrin 5% EC	73.80[ab]	48.50[c]	29.78[c]	22.64[e]	16.23[e]
Control	65.87[b]	76.48[a]	74.97[a]	74.62[a]	72.37[a]
Jhol mal	70.91[ab]	58.52[bc]	48.88[b]	37.00[d]	30.45[d]
Neem cake	71.56[ab]	62.09[b]	52.99[b]	50.00[bcd]	38.82[c]
Yellow sticky trap	71.32[ab]	72.48[a]	65.01[a]	61.14[ab]	58.06[b]
Grand Mean (GM)	71.26	63.95	55.86	49.10	41.97
F-test	NS	***	***	***	***
LSD (0.05)	8.95	0.03	11.09	13.89	6.18
CV (%)	7.06	8.81	11.16	15.90	8.28
SEM (±)	1.09	1.23	1.36	1.70	0.75

CV: Coefficient of Variation; LSD: Least Significant Difference; DAFS: Days After First Spray; Level of significance: *** @0.001% level of significance; ** @0.01% level of significance; *@0.05% level of significance

Table 4: Effect of different treatments on the percentage of fruit infestation on bitter gourd at different intervals during second spray of pesticides at Gokuleshwor, Baitadi (2022/23)

	% Of fruit infestation by fruit flies				
Treatment	**3 DASS**	**6 DASS**	**9 DASS**	**12 DASS**	**15 DASS**
Beauveria	45.22[c]	40.73[b]	33.84[b]	27.23[b]	19.53[b]
Bt	18.57[ef]	10.89[d]	7.14[d]	4.25[d]	3.46[d]
Chlorpyrifos 20% EC +Cypermethrin 5% EC	12.10[f]	8.81[d]	5.95[d]	2.22[d]	1.87[d]
Control	70.74[a]	61.57[a]	54.60[a]	52.06[a]	44.19[a]
Jhol-mol	24.70[e]	17.03[cd]	12.81[c]	7.31[cd]	3.87[d]
Neem cake	32.10[d]	24.56[c]	18.04[c]	13.46[c]	10.87[c]
Yellow sticky trap	55.17[b]	48.16[b]	33.66[b]	27.52[b]	23.37[b]
Grand Mean (GM)	36.94	30.25	23.72	19.51	15.31
F-test	***	***	***	***	***
LSD (0.05)	7.16	7.97	5.62	6.36	4.63
CV (%)	10.89	14.81	13.32	18.67	17.02
SEM (±)	0.87	0.97	0.69	0.78	0.56

CV: Coefficient of Variation; LSD: Least Significant Difference; DASS: Days After Second Spray; Level of significance: *** @0.001% level of significance; ** @0.01% level of significance; *@0.05% level of significance

3.3 % Of fruit weight

The consequences of different treatments in controlling fruit infestation due to cucurbit fruit fly in Bitter gourd based on fruit infestation based on fruit weight (%) has been presented in Table 5 and table 6. Fruit damaged by fruit fly based on fruit weight (%) varied from 73.44 to 78.35 before application of treatment and result found be non-significant among all the treatments (Table 5). At three days after first spray, the untreated control exhibited the highest fruit infestation based on fruit weight (%) which at par with yellow sticky trap and Beauveria. The lowest fruit infestation based on fruit weight (%) was obtained in Chlorpyrifos 50% EC +Cypermethrin 5% EC. This trend continues at 6,9 and 12 days after first spray, indicting the effectiveness of Chlorpyrifos 50% EC +Cypermethrin 5% EC in minimizing fruit damage compared to other treatment. After second the spray, the impact of different treatments on bitter gourd infected by fruit flies was observed. Three days after second spray, the untreated control had the highest fruit infestation based on fruit weight (%) while Chlorpyrifos 50% EC +Cypermethrin 5% EC showed the lowest. Similarly, the trend persisted at 6,9,12 and 15 days after second spray. At 15 days after second spray the highest fruit infestation based on weight (%) was obtained in control and lowest was obtained in Chlorpyrifos 50% EC +Cypermethrin 5% EC which was statistically at par with Bt, Jholmol and Neem cake. Chlorpyrifos 50% EC +Cypermethrin 5% EC consistently demonstrating the most effective reduction in fruit damage compared to the other treatment.

Table 5: Effect of different treatments against fruit fly on weight basis (%) of in bitter gourd at different intervals during before and after first spray of pesticides at Gokuleshwor, Baitadi (2022/23)

		Weight (%) of bitter gourd			
Treatment	**Before spray**	**3 DAFS**	**6 DAFS**	**9 DAFS**	**12 DAFS**
Beauveria	75.42[a]	81.08[ab]	67.34[bc]	53.77[b]	44.95[b]
Bt	76.11[a]	58.87[d]	50.57[d]	37.32[c]	29.24[c]
Chlorpyrifos 50% EC +Cypermethrin 5% EC	73.44[a]	38.32[e]	26.95[e]	19.72[d]	13.14[d]
Control	72.51[a]	85.22[a]	78.98[a]	69.63[a]	64.58[a]
Jhol mal	75.47[a]	62.98[cd]	58.95[cd]	46.29[bc]	31.30[c]
Neem cake	78.35[a]	72.18[bc]	60.35[bcd]	44.13[bc]	29.49[c]
Yellow sticky trap	74.96[a]	82.27[a]	71.30[ab]	54.92[b]	43.71[b]
Grand Mean (GM)	75.18	68.70	59.21	46.54	36.63
F-test	NS	***	***	***	***
LSD (0.05)	6.58	9.39	10.53	10.77	10.71
CV (%)	4.92	7.68	10.00	13.01	16.44
SEM (±)	0.80	1.15	1.29	1.32	1.31

CV: Coefficient of Variation; LSD: Least Significant Difference; DAFS: Days After First Spray; Level of significance: *** @0.001% level of significance; ** @0.01% level of significance; *@0.05% level of significance

Table 6: Effect of different treatments against fruit fly on weight basis (%) of in bitter gourd at different intervals during the second spray of pesticides at Gokuleshwor, Baitadi (2022/23)

	Weight (%) of bitter gourd				
Treatment	**3 DASS**	**6 DASS**	**9 DASS**	**12 DASS**	**15 DASS**
Beauveria	31.45[b]	29.25[b]	22.73[b]	13.76[b]	9.09[b]
Bt	20.73[c]	11.54[d]	7.21[de]	3.20[cd]	1.55[c]
Chlorpyrifos 50% EC +Cypermethrin 5% EC	7.69[d]	5.13[e]	4.08[e]	1.93[d]	0.92[c]
Control	54.80[a]	48.33[a]	47.95[a]	47.29[a]	46.69[a]
Jhol mal	25.85[b]	17.96[c]	10.98[cd]	3.94[cd]	2.04[c]
Neem cake	22.14[c]	17.16[c]	13.80[c]	7.19[c]	3.67[c]
Yellow sticky trap	29.51[b]	24.93[b]	22.17[b]	15.37[b]	10.34[b]
Grand Mean (GM)	27.45	22.04	18.42	13.24	10.61
F-test	***	***	***	***	***
LSD (0.05)	6.41	5.33	5.21	4.63	3.51
CV (%)	13.13	13.60	15.91	19.68	18.59
SEM (±)	0.78	0.65	0.63	0.56	0.43

CV: Coefficient of Variation; LSD: Least Significant Difference; DAFS: Days After First Spray; Level of significance: *** @0.001% level of significance; ** @0.01% level of significance; *@0.05% level of significance

3.4 Yield of Bitter Gourd

The highest marketable yield (Mt/ha) were obtained from Chlorpyrifos 50% EC +Cypermethrin 5% EC treatment i.e., 24.62 Mt/ha followed by Bt i.e., 21.28 Mt/ha and Jholmol 19.77 Mt/ha. The lowest marketable yield was obtained in control (untreated plot) i.e.,10.45 Mt /ha followed by yellow sticky trap and Beauveria marketable yield were 13.55Mt/ha and 13.46 mt/ha, respectively. The coefficient of variation for the total marketable yield of the bottle gourd were 8.10. The efficacy of insecticides based on its effectiveness against fruit flies was Chloropyrifos 20% EC +Cypermethrin 5% EC which exhibits superior and outperforms Bt, Jholmol, Neemcake, Yellow sticky trap and Beauveria.

Table 7: Effect of different treatment on Yield of Bitter gourd at Gokuleshwor, Baitadi (2022/23)

Treatment	Yield (Mt/ha)
Beauveria	13.46[d]
Bt	21.28[b]
Chlorpyrifos 50% EC +Cypermethrin 5% EC	24.62[a]
Control	10.45[e]
Jhol mal	19.77[bc]
Neem cake	18.33[c]
Yellow sticky trap	13.55[d]
Grand Mean (GM)	17.35
F-test	***
LSD (0.05)	2.50
CV (%)	8.10
SEM (±)	0.30

CV: Coefficient of Variation; LSD: Least Significant Difference; Level of significance: *** @0.001% level of significance; ** @0.01% level of significance; *@0.05% level of significance

4. Discussion

The present investigation was conducted entitled 'SUSTAINABLE APPROACHES FOR FRUIT FLY MANAGEMENT IN BITTER GOURD CULTIVATION'.Cucurbit yield and productivity are restricted by a number of biotic factors, including the cucurbit fruit fly has emerged as the main pest over in Nepal for the last few decade (GC and Mandal, 2000; Manjunathan, 1997). In the light of environment conditions and susceptibility of crop species, the losses range in size from 30% to 100% (Dhillon, Naresh, et al., 2005; Dhillon, Singh, et al., 2005a, 2005b; Gupta and Verma, 1992; Shooker et al., 2006). Farmers in Nepal's middle hills tried a variety of management techniques, including traditional (70%), chemical (32%), mechanical (80%) and combination of two or more techniques (68%) are used to fight fruit fly issues (Sapkota, 2009). The previous study showed that bitter gourd was the most preferred host of cucurbit fruit fly (Nath and Bhushan, 2006).

The chemical insecticide and Botanicals/ Bio-pesticides used in this study had a significant effect on the traits observed in Bitter gourd. The efficacy of insecticides (Chloropyrifos 50% EC +Cypermethrin 5% EC, Bt, Jholmol, Neem cake, yellow sticky trap and Beauveria) on fruit fly population, fruit infestation (%), fruit infestation based on weight (%) and Yield was recorded after first and second spray of the treatments. In the different eco-friendly management techniques, chlorpyrifos 50% EC+ Cypermethrin 5% EC were recorded as the most effective. Similar results were obtained in (Toyzhigitova et al., 2019).

Chloropyrifos 20% EC +Cypermethrin 5% EC had recorded the least number of fruit fly followed by Bt, Jholmol, Neem cake after first and second spray. An innovative or unconventional approach to combat extremely resilient insects for optimal control, which could be systemic or contact in nature (Elbert et al., 1998). According to the current study, cypermethrin was successful against the test organism, suggesting that the insecticide interfere with the nervous system's regular processes. Similar results were reported by (Rana et al., 2015). Chloropyrifos 20% EC +Cypermethrin 5% EC reduces the fecundity and inhibit the fertility of fruit fly. Similarly, some researchrs found that the toxic effects of Cypermethrin and Chloropyrifos may cause disturbances in the embryonic stages these results support the current study (Khalequzzaman and Sultana, 2006; Ullah et al., 2006).

Chloropyrifos 20% EC +Cypermethrin 5% EC had recorded the lowest fruit infestation (%). Cypermethrin was effective against fruit infestation in bitter gourd by *B. cucurbitae* (Rabindranath and Pillai, 1986). Lowest infestation of fruit by *B. cucurbitae* was recorded in Cypermethrin (Borah, 1997). The same result was recorded in fruit infestation based on weight (%). The highest marketable yield was also recorded in Chloropyrifos 20% EC +Cypermethrin 5% EC treated plot and lowest in control.

As reported by eco-friendly insecticides like cypermethrin, which were applied one after another as per the schedule, resulted in minimum fruit fly damage in melon fruits (Nath et al., 2007; Waseem et al., 2009). Chlorpyrifos is often said to be a beneficial insecticide because it has a favorable balance of relative toxicity (National Registration Authority for Agricultural and Veterinary Chemicals, 2007). Chlorpyrifos 50% EC and Cypermethrin 5% EC reduce the fecundity and inhibit the fertility of fruit fly so that the damage number of fruit's gets lower, and it was the way to increase the yield. This result was also supported (Sultana et al., 2017; Toyzhigitova et al., 2019).

The results of Bacillus thuringiensis in decreasing the infestation of fruit fly were also supported by the report (Sezen et al., 2010; Shishir et al., 2015). The novel toxicity of Bacillus thuringiensis strains, an entomopathogenic bacterium, would help in developing efficient and eco-friendly control measures for the *Bactrocera cucurbitae* in cucurbit fruit fly, which would decrease the fruit fly infestation and its number with an increase in yield. Bacillus thuringiensis, which prevents the bioaccumulation and biomagnification of toxic substances via the food chain and ensures food security and natural safety, To assess the flight dynamics, we had used a yellow sticky trap, but it caught a large number of fruit fly until the last data was taken, but it did not have a significant effect on the number of fruit fly injuries as well as yield.

Similar results were obtained (Gillani et al., 2002; Toyzhigitova et al., 2019). The neem-based product used in our treatment moderately controls the infestation as well as aids in an increase in yield in comparison with the control treatment; similar results were obtained (Gupta et al., 2020; Dao et al., 2020). In our results, Neem and Jholmol based treatments both controlled the fruit fly and increased the yield, which were statistically at par as these results were supported by few researcher, i.e., 24.44% (Adhikari et al., 2020). The result from present investigation revealed that better efficacy of Chloropyrifos 20% EC +Cypermethrin 5% EC in term of marketable yield, lowest fruit infestation by number and by weight and insect population followed by Bt, Jholmol and neem cake.

5. Conclusion

Melon fruit fly *(Bactrocera cucurbitae*) (Diptera: Tephritidae) is one of the devastating pests found to be damaging bitter gourd production. In Nepal, yield losses of up to 35% were recorded in Momordica charantia by insects and pests. Bitter gourd is the most affected plant by the melon fruit fly. Hazardous use of pesticides to control pests has adverse effects on the environment and increases the chance of bioaccumulation, biomagnification, pest resurgence, harmful effects on pollinators and natural enemies, and also affects human health. The realization of the negative impact of the pesticide leads to the search for an eco-friendly management of melon fruit flies, which includes microbial approaches with antagonistic entomopathogenic fungi and botanical pesticides as the best alternative to chemical pesticides.

In Baitadi district, about 20 ha of land are under bitter gourd cultivation, whose productivity is 8.05 tones/ha MOALD, 2020/21), which is quite low. The main reasons behind its poor performances are poor agricultural practices, local innovation, and the majority of infections by disease and insect pests. The fruit fly infection is severe in the research area, and as a result, yield losses in melon production are faced by farmers, and farmers are unaware of effective management of fruit fly infestations on bitter gourds. Thus, the study on eco-friendly management of fruit flies on bitter gourd allows us to know the intensity of infestation of fruit flies on bitter gourd and its extent of damage, along with the evaluation of effective control tactics. Locally available materials and biopesticides such as Bacillus thuringiensis, Beauveria bassiana, Jhol mol, Neem cake, yellow sticky trap, etc. are considered the best options for management.

The Chloropyrifos 20% EC +Cypermethrin 5% EC treatment resulted in the lowest in fruit fly population, percent of fruit infestation, percent of fruit infestation based on weight, and Yield. Similarly, the highest marketable yield was obtained from Chloropyrifos 20% EC +Cypermethrin 5% EC (24.62 mt/ha) and Bt (21.28 mt/ha) which was followed by Jholmol (19.77 mt/ha), Neem cake (18.33 mt/ha), Yellow sticky trap (13.55 mt/ha), Beauveria (13.46 mt/ha) and control (10.45 mt/ha). The efficacy of insecticides based on its effectiveness against fruit flies was Chloropyrifos 20% EC +Cypermethrin 5% EC which exhibits superior and outperforms Bt, Jholmol, Neemcake, Yellow sticky trap and Beauveria. Chloropyrifos 20% EC + Cypermethrin 5% EC stands out as the best treatment for reducing the incidence of cucurbit fruit flies, according to an analysis of the data. This treatment greatly increases the amount of bitter gourd produced while also reducing the infestation of fruit flies. While Bt is the most effective treatment against fruit fly after Chloropyrifos 20% EC +Cypermethrin 5% EC also have significant potential due to their efficacy to increase yield of Bitter Gourd.

However, the study was concentrated on restricted geographical region with limited number of insecticides. It would be difficult to draw firm conclusion about environmentally friendly fruit fly management in bitter gourd only on these findings. Research on the possible effects of botanicals and bio-pesticides can be more thorough if it is conducted over several seasons, which is currently not being done. However, it is critical to recognize the risk associated with chemical insecticides which are harmful to human health, the environment, beneficial insects and animals and they may couple with the potential long-term issues like pest resistance and resurgence. Chemical pesticides are still required for the short-term management of bitter gourd, but it's crucial to take into account their long-term effects as well because you can't ignore them. Based on observations, Bacillus thuringiensis an environmentally friendly substitute showed exceptional effectiveness in controlling fruit flies. Moreover, Jhol-mol and neem cake have proven to be workable, affordable, and ecologically friendly alternatives in cases where Bacillus thuringiensis is unavailable. It becomes vital to balance long-term environmental concerns with short-term efficacy when creating sustainable fruit fly management techniques.

The study emphasizes the pivotal role of sustainable pest management techniques in order to increase bitter gourd productivity as well as to reduce negative impacts on the environment and public health. Ecofriendly and effective pest control measures should be adapted for sustainable management of bitter gourd since the lowest yield was obtained from control field.

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