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Research Article

Evaluation of Efficacy of Certain Pesticides and Black Plastic Mulch as an approach of developing Integrated Pest Management for Melon fruit fly (*Bactrocera cucurbitae*)

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Abstract

A field experiment was conducted at Pyuthan Municipality, Pyuthan district of the Federal Democratic Republic of Nepal to develop an integrated pest management strategy against melon fruit fly (*Bactrocera cucurbitae*). The experiment was laid out in two factorial Randomized Complete Block Design (RCBD). The first factor was different doses of pesticides; Spinosad (45% SC) @ 1ml/3l water, Cypermethrin (10% EC) @5ml/20l water and, botanical Jholmol @ 1:3 ratio (1 part Jholmol and 3 part water). The second factor was Black plastic mulch and no mulch. The pesticides were applied at 9-day intervals and data on fruit infestation, ovary damage, yield and, post-set damage were collected at 3 day intervals and the data analysed using R Studio. The result revealed highly significant differences among mulching and non-mulching plots. Mulching plots had the lowest fruit infestation (3.95%), lowest ovary damage (0.88%), lowest post-set damage (2.38%) and, higher yield per plot (21.25 kg) than non-mulched plots. Highest protection against melon fruit fly was observed by Spinosad at the third spray; percentage of fruit infestation (3.71%), ovary damage (0.76%) and yield (20.20 kg/plot) followed by Cypermethrin and Jholmol. The highest protection was obtained by the application of Cypermethrin (1.78%) at the post-set stage followed by Spinosad and Jholmol. The application of Spinosad, Cypermethrin alone with black plastic mulch provided superior protection than Jholmol and control. However, the pest reduction and yield observed on the treatments with the combination of Jholmol and black plastic mulch was satisfactory (21.87 kg/ha) than control (14.58 kg/ha).

Keywords: IPM; Bactrocera cucurbita; Control; Yield.

Introduction

Cucumber *Cucumis sativus* L. (2n = 14) is an annual, summer season, trailing type of plant belonging to the family Cucurbitaceae (Swamy, 2023). It can be cultivated under the wide range of climatic variation ranging from tropics to temperate region on the altitude range of 100 to 1800 meters from the sea level (Khanal *et al*., 2020). This is one of the most popular, widely consumed vegetable commodities in Nepal due to its high nutritional value (Mallic, 2022), high benefit cost ratio (1.59) (Lutfa *et al*., 2019), easiness of growing and economic profitability (Maurya *et al*., 2015). A total of 152,862 metric tons of cucumber was produced from 9,978 ha of land in Nepal on year 2020/21 with productivity of 15.32 t/ha (MoALD, 2022). This production is 19.49% more than that produced on year 2012/2013 (MOALD, 2022).

Despite the economic profitability, and easiness of growing, several constraints hinder the production of this multipurpose commodity in Nepal. Striped cucumber beetle (*Acalymma vittatum*), spotted cucumber beetle (*Diabrotica undecimpunctata*), Melon fruit fly (*Bactrocera cucurbitae)*, Red Pumpkin Beetle (*Raphidopalpa foveicollis*), Aphids (*Myzus persicae* and *Aphis gossypii*), and White fly (*Bemisia Tabaci*) are some of the common pests of cucumber in Nepal (Sharma *et al*., 2016). Among them, Melon fruit fly *Bactrocera cucurbitae* (Diptera-Tephritidae) is a serious pest of cucumber which infests around 70 host plants, belonging to the family cucurbitaceous and other host species (Dhillon *et al*. 2005). Melon fruit fly damage can range from 95% in bitter gourd and snake gourd, 38.69% - 90% in cucumber, 29% in melon, and 60-87% in pumpkin fruit (Gyawali *et al*., 2023).

Both adult and larva of melon fruit fly damage the young fruits and flowers making them unfit for human consumption (Nasiruddin *et al*., 2004). The females prefer young, green and tinder fruits to lay the eggs, 2 to 4 mm deep in the fruit pulp (Dhillon *et al*., 2005). The recently laid eggs are bright white, slightly curved, and tapered at one end and rounded on another, typically hatching in around 1.1 to 1.8 days in cucumber (Mir *et al*., 2014). The recently hatched larva are called maggots, which feed inside the developing fruits. The eggs are also laid in the corolla of the tinder flowers, stems and, the maggots feed on the flowers and inner flesh of the stems (Gyawali *et al*., 2023). The damaged is caused by the growing maggots inside the tinder fruits, flowers and stems which make them vulnerable to bacterial and fungal growth, subsequently causing decay of affected fruits, flowers and stems (Ronald and Jayma, 2007).

Integrated pest management (IPM) is an approach of pest control in which pest population is supressed below the threshold level by the combined method of different pest management techniques, such as chemical, biological, cultural and physical methods (Gyawali *et al*., 2023). Since, the maggots damage the fruits internally, it is difficult to control this pest with insecticides alone. Pesticides alone cannot reach the growing larva; therefore measures should be taken to destroy, adults, growing maggots by developing an integrated control strategy for effective management of this pest. In a report, it was revealed that, around 73% of Nepalese farmers experienced health related issues who frequently applied chemical pesticides in their field (Karki and Dangol, 2023). Haphazard and irrational use of chemical pesticides not only result adverse health effects on farmers but also lead to the risk of pest resurgence and pesticides resistance on insects and pests (Zhang *et al*., 2021). Some of the widely used pesticide such as Imidacloprid, Pyrenthroid, chlorantraniliprole has developed resistance in the common fruit fly, Fallarmyworm, and diamond back moth respectively (Gyawali *et al*., 2023). It is necessary to explore different control measures, based on the availability of resources in the locality.

Objectives

General Objective

The objective of the study was to evaluate the level of infestation by melon fruit fly on flower, fruit and ultimately on yield of cucumber on different treatments, using certain pesticides, and under mulching and non-mulching condition as an approach for integrated pest management.

Specific Objectives

- To evaluate the effect of mulching and certain pesticides on percentage of ovary damage.
- To evaluate the effect of mulching and certain pesticides on percentage of fruit damage.
- To evaluate the effect of mulching and certain pesticides on percentage of post-set damage.
- To evaluate the effect of mulching and certain pesticides on the yield of the cucumber

Materials and Methods

Location of the site / Site selection

The study was conducted at the Maranthana village area, Pyuthan Municipality, Pyuthan district, Lumbini province of Federal Democratic Republic of Nepal from February 20 to July 7, 202 (Fig. 1). The site was located at the 28.11°N latitude and 82.91°E longitude. The site was selected under the guidance of site supervisor at PMAMP, Project Implementation Unit (Vegetable - zone), Pyuthan. The site had suitable environmental condition for carrying out the experimental research. The site was selected on the basis of suitable water availability, access to road and market.

Metrological Condition of Research Site

Metrological data was collected from online weather platform Accuweater (https://www.accuweather.com/) for the research site from February to June 2023 (Fig. 2).

Experimental Design

The study was based on two factorial Randomized Complete Block Design (RCBD) (Fig. 3). A total of eight treatments and three replications were set to the experiment. The treatments were assigned at random to each block. The size of each plot was assigned as 8 m^2 (2*4m). A distance of 1m was set in between each block and a distance of 0.5m was set in between each two plots. A total of 8 plants with spacing of 1*1m plant to plant and row to row was maintained. Rajha variety of cucumber was selected for the experimental research as per the recommendation of site supervisor, farmers and major advisor. A space of 0.5 meters was left as a bund on every corner of the experimental site. Following treatments were used in the research (Table 1).

Fig. 1: Map of Nepal showing study area

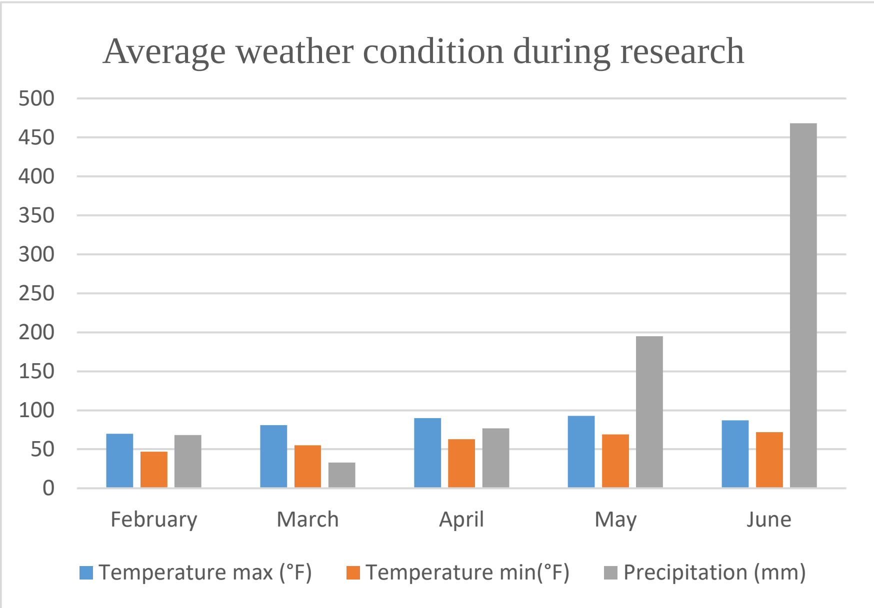

Fig. 2: Average temperature and precipitation during research

Table 1: Treatments used in the experiment and their description

Treatment symbol	Description
T1	Mulching + Spinosad
T2	Mulching + Cypermethrin
T3	Mulching + Jholmol
T4	Mulching only
T5	No mulching + Spinoad
T6	No mulching + Cypermethrin
T7	No mulching + Jholmol
T8	No mulching

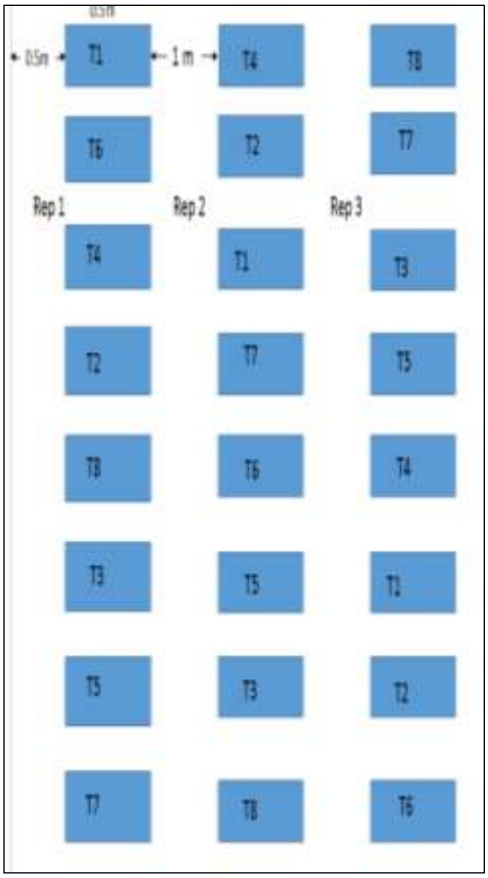

Fig. 3: Diagrammatic representation of research plot

Data Collection and Analysis

Five plants from each experimental plot were randomly selected as sample plants for data collection. Observations were recorded 3, 6 and 9 days after spray application. Total number of female flowers were counted from each sample plant at three days intervals. The observations were recorded on ovary damage, post-set damage (PSD), fruit infestation/damage and yield starting from flowering till the last harvest.

Ovary/Pre-set damage:

Damaged number of unopened female flowers (Ovary) due to cucurbit fruit fly infestation per plant.

$$\text{Ovary damage (\%)} = \frac{\text{No. of ovary damage}}{\text{Total No. of female flowers per plant}} \times 100$$

Post-set damage:

Just after set young and immature fruits damaged due to cucurbit fruit fly having less than 100 g in weight.

$$\text{PSD (\%)} = \frac{\text{No. of PSD fruits due to fruit fly per plant}}{\text{Sum of total set fruit per plant}} \times 100$$

Percentage of fruit infestation:

Unmarketable fruit due to cucurbit fruit fly during harvesting having equal or more than 100 g in weight.

$$\text{Harvest Damage (HD)(\%)} = \frac{\text{No. of HD fruits due to fruit fly per plant}}{\text{No. of total set fruit per plant}} \times 100$$

Harvest Damage (HD) (%) = (No. of HD fruits due to fruit fly per plant/No. of total set fruit per plant) × 100.

The final data was analysed and significance of treatments was assessed to make a valuable conclusion. The data was analysed using Microsoft excel 2021 and R-studio program.

Soil Characteristics

The field soil was analysed for the soil characterization of its nutrient value (Table 2). Nitrogen, phosphorous and potassium level were determined along with soil pH. The samples of soil were taken from multiple positions within the field by making "W" shape imaginary line in the research field. The composite soil was then thoroughly dried under shade, pebbles, roots were removed and thoroughly crushed to make fine soil dust. One fourth of the soil was removed and other soil part was taken for analysis. The table below shows the nutrient condition of the research field at the time of carrying out experimental research.

Table 2: Soil characteristic of research field

Particulars	**Soil pH**	**Nitrogen**	**Phosphorous**	**Potassium**
Status	6.5	Medium	low	Medium

Selection of Pesticides for research and Method of Application

Two chemical and one botanical pesticide were selected for the experiment as a possible control measure of *Bactrocera cucurbitae* during the research (Table 3). Spinosad 45% SC and Cypermethrin 10% EC were selected as a possible chemical pesticide for carrying out the research. Jholmal 2 was used as a possible botanical that can supress large species of plant pests. Jholmal-2 and Jholmal-3 has been known to control insect/pest attacks and protect crops against fungal and vector-borne diseases (ICIMOD, 2020). The pesticides were received from the genuine authentic distributor. Jholmol 2 was prepared locally by using locally available botanicals, cow dung, packed into the dark polythene formulated basket for 15 days.

Jholmol Preparation - Locally sourced plants with insecticidal or insect repellent properties, were mixed with animal urine and water at a ratio of 1:5:5. The mixture was ready for use in three weeks. The mixture was filtered, mixed with water @ 1:3, and then sprayed on the leaves and stems of the plant to control various diseases and insect pests.

Table 3: Pesticides used during the study

S.N.	Common name	Trade name	Formulation	a.i.	Dose	Manufacturer country
1	Spinosad	Tracer	SC	45%	1ml/3l water	India
2	Cypermethrin	Summit-10	EC	10%	5ml/20l water	India
3	Jholmol	No trade name	-	-	1:3 Jholmol/water	Locally made

Insecticides were sprayed at 9 days interval. First spray was done at 8 weeks after transplantation and after obtaining 2 pre-spray harvest at 3 days interval. The first spray was done after 2 pre spray harvest at 3 days interval. Then, the insecticides were applied at 9 days interval using knapsack sprayer. Personal protective gears such as globes, mask, protective goggles were used for the safety of the operating personnel.

Result

Fruit Infestation

Different pesticides showed significant reduction in the pest infestation at both mulching and non-mulching conditions (Table 4). The use of mulching showed significant difference in the percentage of fruit infestation at all the dates of observation. The minimum infection was observed after third spray of pesticide (3.95%) in mulching condition than the non-mulching condition (23.09%) at pre spray. The intensity of pest infection was reported to be decreasing on non-mulching condition when pesticides were sprayed at different days on mulched plots. However, the overall fruit infection was found significantly high than those on mulching condition on field. This could be because of reducing pest population at the overall field due to continuous pesticide application.

Both chemical pesticides; Spinosad and Cypermethrin and botanical pesticide; Jholmol showed significant reduction in fruit infection at different days of observation. Highest fruit infection was observed in control (21.25%) at pre-spray condition. Lowest fruit infection was observed in plots treated with cypermethrin (9.70%) followed by spinosad (11.6%), and jholmol (12.08%) at First spray. The lowest fruit infection was observed in fields treated with spinosad (5.26%) followed by cypermethrin (5.49%) and Jholmol (9.36%) at second spray. Lowest fruit infection was observed in fields sprayed with spinosad (3.71%) followed by cypermethrin (4.75%) and Jholmol (9.27%) at third spray. The data suggest that, application of anyone of the spinosad, cypermethrin and jholmol in combination with black plastic mulch can significantly reduce the fruit infection at field condition. However, use of chemical pesticide was found superior in terms of pest control than jholmol.

Analysis of data revealed that for the different combinations of treatments, plots treated with Cypermethin + Mulching showed superior protection against melon fruit fly (1.44%) followed by Spinosad + Mulching (1.95%) and Mulching + Jholmol (6.35%) & Mulching only (5%) (Table 5). Highest fruit infestation was observed in control (33.62%) followed by No mulching + jholmol (11.13%). Application of Spinosad and Cypermethrin resulted better control in non-mulched plots than the control plot. However, the control achieved was not much satisfactory as compared to the mulched plots. Treatment combination of Cypermethrin + Black Plastic Mulch is thus superior for controlling melon fruit fly in controlling fruit damage in cucumber.

Table 4: Effect of mulching and different pesticide on fruit infection

Treatment		Fruit Infestation percentage			
Mulching		**Pre-Spray**	**First Spray**	**Second Spray**	**Third Spray**
	Mulching	13.748^{b}	9.23^{b}	4.80^{b}	3.95^{b}
	Non-Mulhcing	23.099^{a}	18.07^{a}	14.99^{a}	12.25^{a}
	LSD (0.05)	3.192	3.192	3.26	3.94
	SEm (±)	0.36	0.61	0.53	0.64
	F-probability	***	***	***	***
	CV%	19.78	31.13	37.58	55.56
Pesticide					
	Spinosad	17.40	11.26^{a}	5.26^{a}	3.71^{a}
	Cypermethrin	18.71	9.70^{a}	5.49^{a}	4.75^{a}
	Jholmol	16.31	12.28^{a}	9.36^{a}	9.27^{ab}
	Control	21.25	21.01^{b}	19.47^{b}	14.69^{b}
	LSD (0.05)	4.51	5.26	4.60	5.57
	SEm(±)	0.37	0.43	0.38	0.46
	F-probability	Ns	**	***	**
	CV%	19.78	31.13	37.58	55.56
	Grand Mean	18.42	13.13	9.89	8.10

[Note: CV: Coefficient of variation, LSD: Least significant difference: Means followed by the same letter in a column are not significantly different by DMRT at 5% level of significance, SEm(±): Standard error of mean, ***: significant at 0.001, **: significant at 0.01 and *: significant at 0.05 level, NS: Not-significant]

Table 5: Fruit infection percentage at different treatments

Treatments	Fruit Infestation percentage			
	Pre-spray infestation	**Infestation at 1st Spray**	**Infestation at 2nd Spray**	**Infestation at 3rd Spray**
Mulching + Spinosad	16.79bc	9.23b	3.28c	1.95c
Mulching + Cypermethrin	12.87c	6.90b	2.90c	1.44c
Mulching + Jholmol	13.92c	11.56b	6.35bc	7.40bc
Mulching Only	11.41c	9.21b	6.67bc	5.00bc
No mulching + Spinosad	18.01bc	13.18b	7.22bc	5.46bc
No mulching + Cypermethrin	24.56ab	12.5b	8.08bc	8.05bc
No mulching + Jholmol	18.71bc	12.98b	12.36b	11.13b
Control	31.10a	33.62b	32.28a	24.38a
LSD (0.05)	7.44	7.57	6.51	7.88
SEm (±)	0.30	0.30	0.26	0.32
F-Probability	***	***	***	***
CV%	23.07	31.70	37.58	55.56
Grand Mean	18	13.65	9.89	8.10

[Note: CV: Coefficient of variation, LSD: Least significant difference: Means followed by the same letter in a column are not significantly different by DMRT at 5% level of significance, SEm(±): Standard error of mean, ***: significant at 0.001, **: significant at 0.01 and *: significant at 0.05 level, NS: Not-significant]

Ovary Damage/Pre-set Damage

Different pesticides showed significant reduction in the percentage of ovary damage in both mulching and non-mulching condition (Table 6). At pre-spray, 2.78% of ovary were reported to be damaged at mulched plots which was significantly lower than on non-mulched plot (3.57%). After the sprays of different pesticides, ovary damage was found to be significantly reduced at mulching condition than on the non-mulching condition. Lowest ovary damage were observed on third spray (0.88%) followed by second spray (1.02%) and first spray (1.93%) at mulching condition than any of the non-mulching condition.

Application of different pesticides; Spinosad, Cypermethrin and Jholmol showed significant reduction in the percentage of ovary damage at different stages of spray. At first spray, lowest ovary damage was observed in plots treated with cypermethrin (1.7%) followed by Spinosad (2.2%) and Jholmol (2.38%). Highest ovary damage was observed at control (3.91%) in first spray of pesticide. At second spray, lowest ovary damage was observed on plots treated with cypermethrin (1.0%) followed by Spinosad (1.05%) and Jholmol (1.83%). At third spray, lowest ovary damage was observed on plots treated with Spinosad (0.76%) followed by cypermethrin (0.83%), and Jholmol (1.83%). The extent of ovary damage was also found reduced in controlled plots during the subsequent period of pesticide application in different treatment plots. This could have had happened due to the continuous pesticide application in the field for extended period of time that resulted in the overall pest population reduction in the field

Table 6: Effect of mulching and pesticides on ovary damage

	Treatment	**Pre-Spray**	**Infection_1st Spray**	**Infection_2nd Spray**	**Infection_3rd Spray**
Mulching					
	Black polythene	2.78a	1.93a	1.02a	0.88a
	Non-Mulching	3.57b	3.17b	2.75b	2.17b
	LSD (0.05)	0.61	0.83	0.73	0.85
	SEm (±)	0.10	0.13	0.12	0.14
	F-probability	*	**	***	**
	CV%	22.35	37.46	44.13	64.15
Pesticide					
	Spinosad	3.29a	2.2a	1.055a	0.76a
	Cypermethrin	3.13a	1.7a	1.00a	0.83a
	Jholmol	2.90a	2.38a	1.83a	1.83ab
	Control	3.36a	3.91b	3.67b	2.67b
	LSD (0.05)	0.878	1.18	1.032	1.21
	SEm (±)	0.072	0.09	0.085	0.099
	F-probability	NS	**	***	*
	CV%	22.34	37.46	44.13	64.15
	Grand Mean	3.17	2.55	1.88	1.52

[Note: CV: Coefficient of variation, LSD: Least significant difference: Means followed by the same letter in a column are not significantly different by DMRT at 5% level of significance, SEm(±): Standard error of mean, ***: significant at 0.001, **: significant at 0.01 and *: significant at 0.05 level, NS: Not-significant]

Analysis of data revealed that for the different combinations of treatments, plots treated with Cypermethin + Mulching showed superior protection against melon fruit fly (1.67%) at second spray followed by Mulching + Jholmol & Mulching only (2%), and Spinosad + Mulching (2.2%) (Table 7). However, at third spray better control was observed in plots treated with Spinosad in mulching condition (0.80%) followed by treatment Mulching+Spinosad (1.90%) and Jholmol + Mulching (1.90). Highest pre-set damage was observed in control (4.78%) followed by non-mulched plots and mulched plots. Application of Spinosad (1.33%) and Cypermethrin (1.36%) resulted better control in non-mulched plots than the control plot (4.78%). However, the control achieved was not much satisfactory as compared to the mulched plots. Treatment combination of Cypermethrin+Black Plastic Mulch or Spinosad+Black Plastic Mulch is thus superior for controlling melon fruit fly in controlling pre-set damage in cucumber.

Yield

Application of different pesticides showed significant difference on the yield of marketable fruit produced under the mulching and non-mulching condition. The yield is based on production per 8m^2 of land obtained from 5 sample plants. Highest marketable yield was observed on all mulching plots than on the non-mulching plots. Highest marketable yield (21.25kg) was obtained in plots with mulching at third spray. This suggest that, mulching results in enhanced yield than the non-mulching condition providing other conditions same (Table 8).

Table 7: Effect of different treatments on the pre-set/ovary damage of cucumber

Treatment	Pre-spray pre-set damage	Pre-set damage at 1st Spray	Pre-set damage at 2nd Spray	Pre-set damage at 3rd Spray
Mulching + Spinosad	4.00^{ab}	2.23^{de}	2.2^{b}	0.80^{b}
Mulching + Cypermethrin	4.06^{ab}	1.87^{e}	1.67^{b}	1.09^{b}
Mulching + Jholmol	3.67^{b}	1.83^{e}	2.00^{b}	1.90^{b}
Mulching Only	3.48^{b}	2.63^{bcd}	2.00^{b}	1.86^{b}
No mulching + Spinosad	5.33^{a}	2.40^{cd}	1.67^{b}	1.33^{b}
No mulching + Cypermethrin	5.33^{a}	2.73^{bc}	2.06^{b}	1.36^{b}
No mulching + Jholmol	5.00^{ab}	3.00^{b}	2.06^{b}	1.86^{b}
Control	5.50^{a}	5.20^{a}	5.80^{a}	4.78^{a}
LSD (0.05)	1.48	0.44	0.77	1.46
SEm (±)	0.06	0.05	0.03	0.06
F-Probability	*	**	***	**
CV%	18.67	9.36	18.16	44.65
Grand Mean	4.55	2.73	2.43	1.87

[Note: CV: Coefficient of variation, LSD: Least significant difference: Means followed by the same letter in a column are not significantly different by DMRT at 5% level of significance, SEm(±): Standard error of mean, ***: significant at 0.001, **: significant at 0.01 and *: significant at 0.05 level, NS: Not-significant]

Table 8: Effect of different treatment in the yield of the cucumber (Yield/8m^2) in Kg

	Treatment	Pre-Spray yield (kg)	Yield_1st Spray(kg)	Yield_2nd Spray (kg)	Yield_3rd Spray (kg)
Mulching					
	Black polythene	17.25^{a}	18.91^{a}	20.20^{a}	21.25
	Non-Mulching	11.91^{b}	14.08^{b}	14.88^{b}	15.67
	LSD (0.05)	0.957	0.802	0.949	1.539
	SEm (±)	0.157	0.132	0.156	0.253
	F-probability	***	***	***	***
	CV%	7.456	5.551	6.09	9.7
Pesticide					
	Spinosad	15.55^{a}	17.83^{a}	19.50^{a}	20.20^{a}
	Cypermethrin	15.33^{a}	16.33^{b}	18.00^{b}	19.17^{a}
	Jholmol	14.83^{ab}	17.16^{ab}	18.10^{b}	18.67^{ab}
	Control	13.67^{b}	14.67^{c}	15.25^{c}	16.00^{b}
	LSD (0.05)	1.35	1.22	1.34	2.17
	SEm (±)	0.11	0.093	0.11	0.179
	F-probability	*	***	***	*
	CV%	7.456	5.55	6.093	9.7
	Grand Mean	14.67	16.5	17.795	18.125

[Note: CV: Coefficient of variation, LSD: Least significant difference: Means followed by the same letter in a column are not significantly different by DMRT at 5% level of significance, SEm(±): Standard error of mean, ***: significant at 0.001, **: significant at 0.01 and *: significant at 0.05 level, NS: Not-significant]

The application of different pesticides showed significant difference on the yield of marketable yield produced. At first spray, highest yield (17.83kg) was observed in plots treated with spionsad followed by Jholmol (17.16kg) and Cypermethrin (16.33kg). Lowest marketable yield was produced in control (14.67kg). At second spray, highest marketable yield was obtained in fields treated with Spinosad (19.50kg) followed by Cypermethrin (18.10kg), and Jholmol (18%). At third spray, highest marketable yield was observed in fields treated with Spinosad (20.20kg) followed by Cypermethrin (19.17) and Jholmol (18.67%). The application of chemical pesticides Spinosad and Cypermethrin and, Jholmol all were found to be effective in controlling *Bactrocera cucurbiate* and improving yield.

Analysis of data revealed that the production of cucumber under mulching condition with pesticide Spinosad resulted to an increase yield up to 10.67 Mt/ha when compared to non-mulching condition (Table 9). Use of pesticides resulted significantly high yield in the plots with mulching or mulching alone than the non-mulching field condition. The highest yield was observed on mulching condition treated with pesticides Spinosad (23.67 Mt/ha) at 3rd spray followed by Cypermethrin (21.33 Mt/ha), Jholmol (20.40 Mt/ha) and mulching only (19.00 Mt/ha). The least yield was observed on field with no mulch and pesticide used (14.58 Mt/ha). Thus, the treatment combination of Mulching and Black Plastic Mulch is superior in terms of yield production.

Post Set Damage

Application of different pesticides showed significant difference among the percentage of post set damage among mulched and non-mulched plots. Post set damage of cucumber fruit was observed higher in non-mulched plots than the mulched one. Higher post set damage (5.46%) was observed in non-mulched plots at prespray. Lowest post-set damage was observed at third spray in mulched plots (2.38%) (Table10).

Application of different pesticides showed significant difference among the extent of post-set damage. At first spray, lowest post-set damage was observed in plots treated with cypermethrin (2.30%) followed by spinosad (2.48%) and jholmol (2.58%). At second spray, lowest post set damage was observed in plots treated with cypermethrin (1.91%) followed by spinosad (2.06%) and jholmol (2.36%). At third spray, lowest post set damage was observed in plots treated with cypermethrin (1.78%) followed by spinosad (1.88%) and jholmol (1.98%). The extent of post set damage remained at the same constant close range in control plots (Table 10).

Analysis of data revealed that for the different combinations of treatments, plots treated with Cypermethin + Mulching showed superior protection against melon fruit fly (0.33%) followed by Spinosad + Mulching (0.52%) and Mulching + Jholmol & Mulching only (1%) (Table 11). Highest fruit infestation was observed in control (4.33%) followed by No mulching+jholmol (2%). Application of Spinosad and Cypermethrin resulted better control in non-mulched plots than the control plot. However, the control achieved was not much satisfactory as compared to the mulched plots. Treatment combination of Cypermethrin + Black Plastic Mulch is thus superior for controlling melon fruit fly in controlling post-set damage in cucumber.

Table 9: Effect of different treatments on the yield of cucumber (Mt/ha)

Treatment	Pre_spray Yield	Yield at 1st Spray	Yield at 2nd Spray	Yield at 3rd Spray
Mulching + Spinosad	17.33a	20.33a	22.67a	23.67a
Mulching + Cypermethrin	17.33a	18.67b	21.00ab	21.33ab
Mulching + Jholmol	17.33a	18.67b	19.67bc	20.40b
Mulching Only	17.00a	18.00b	18.83c	19.00bc
No mulching + Spinosad	13.67b	15.67c	16.53d	16.33cd
No mulching + Cypermethrin	13.00b	15.33c	16.33d	16.33cd
No mulching + Jholmol	11.67bc	14.00c	15.00d	14.93de
Control	10.00c	11.33d	12.33e	13.00e
LSD (0.05)	1.91	1.60	1.89	3.07
Sem (±)	0.07	0.06	0.07	0.12
F-Probability	***	***	***	***
CV%	7.45	5.55	6.09	9.70
Grand Mean	14.67	16.5	17.79	18.13

[Note: CV: Coefficient of variation, LSD: Least significant difference: Means followed by the same letter in a column are not significantly different by DMRT at 5% level of significance, SEm(±): Standard error of mean, ***: significant at 0.001, **: significant at 0.01 and *: significant at 0.05 level, NS: Not-significant]

Table 10: Effect of different treatments on post set damage of cucumber

	Treatment	Prespray postset damage	Postset damage_1st Spray	Postset damage_2nd Spray	Postset damage_3rd Spray
Mulching					
	Black polythene	4.01a	2.44a	2.53a	2.38a
	Non-Mulching	5.46b	3.58b	3.26b	2.97b
	LSD (0.05)	0.67	0.55	0.37	0.856
	Sem (±)	0.11	0.09	0.06	0.08
	F-probability	***	***	***	**
	CV%	16.23	20.93	14.96	36.44
Pesticide					
	Spinosad	4.67ab	2.48b	2.06b	1.88b
	Cypermethrin	4.53ab	2.30b	1.91b	1.78b
	Jholmol	4.33b	2.58b	2.36b	1.98b
	Control	5.42a	4.68a	5.16a	5.05a
	LSD (0.05)	0.95	0.78	0.53	0.855
	Sem (±)	0.07	0.06	0.04	0.06
	F-probability	NS	*	**	**
	CV%	16.23	20.93	14.96	36.44
	Grand Mean	4.7375	3.01	2.87	2.68

[Note: CV: Coefficient of variation, LSD: Least significant difference: Means followed by the same letter in a column are not significantly different by DMRT at 5% level of significance, SEm(±): Standard error of mean, ***: significant at 0.001, **: significant at 0.01 and *: significant at 0.05 level, NS: Not-significant]

Table 11: Effect of different treatments on post-set damage of cucumber

Treatment	Pre-spray post set damage	Post set damage at 1st spray	Post set damage at 2nd Spray	Post set damage at 3rd Spray
Mulching + Spinosad	4.50a	2.06b	0.77bc	0.52b
Mulching + Cypermethrin	3.76ab	1.40b	0.67c	0.33b
Mulching + Jholmol	3.58abc	2.43b	1.33bc	1.67b
Mulching Only	3.00bc	1.83b	1.33bc	1.00b
No mulching + Spinosad	3.00bc	2.33b	1.33bc	1.00b
No mulching + Cypermethrin	2.80bc	2.00b	1.33bc	1.33b
No mulching + Jholmol	2.50bc	2.33b	2.33b	2.00b
Control	2.23c	6.00a	6.00a	4.33b
LSD (0.05)	1.24	1.67	1.45	1.71
Sem (±)	0.05	0.06	0.06	0.07
F-Probability	*	**	***	**
CV%	22.34	37.46	44.13	64.16
Grand Mean	3.17	2.55	1.88	1.52

[Note: CV: Coefficient of variation, LSD: Least significant difference: Means followed by the same letter in a column are not significantly different by DMRT at 5% level of significance, SEm(±): Standard error of mean, ***: significant at 0.001, **: significant at 0.01 and *: significant at 0.05 level, NS: Not-significant]

Discussion

All insecticides Spinosad (1ml/3l water), Cypermethrin (5ml/20l water) and Jholmol (appropriate dilute concentration) were found significantly effective in reducing the infestation of *Bactrocera cucurbiate* at pre-set, post set, percentage infection of fruit at all days of observation. All insecticides were found effective on improving yield and reducing pest infestation. Use of black plastic mulch was found highly effective in improving yield and reducing any type of pest infestation at different stage of plant growth. The results are in accordance with that of Mutetwa and Mtaita (2014) who has reported that the reflective plastic mulch suppress many insect pests and enhance crop productivity in cucumber. Subedi *et al*. (2021) found zero damage by fruit flies on cucumber when black plastic mulch was applied in association with net house. The use of black plastic mulch disrupts the life cycle of melon fruit flies by preventing maggots from pupating in the soil and eventually reducing the pest population (Subedi *et al*., 2021). Alptekin and Gürbüz (2022) & Hutabarat *et al.* (2021) has also shown the effect of mulching on the pest control, weed reduction, improving overall performance, and yield of cucumber. Thus, black plastic mulch can be used as an effective measure to reduce infestation of many insect pests alone with *B. cucurbitae*.

All the insecticides employed during the research resulted into the profound control of melon fruit fly. The results are in accordance with that of Gautam *et al.* (2021) who found that the spinosad provided effective protection against melon fruit flies followed by dichlorvos, lambda-cyhalothrin, Jholmal, and Azadirachtin on bottle gourd. Abrol *et al*., 2019 and Bhowmik *et al*., 2014 reported spinosad @ 0.002% and 60g/ha to be highly effective in controlling fruit flies in bottle gourd and bitter gourd respectively. The spinosad (200 ml/ha) treated plot against fruit fly infestation on cucumber produced the highest mean marketable fruit production as shown by Shivangi and Swami (2017). The effective control of melon fruit fly using cypermethrin has been shown by Toyzhigitova *et al*., 2019 who reported that the combination of the four insecticides: thiamethoxam/lambda-cyhalothrin and chlorpyrifos/cypermethrin, was more effective in controlling the melon fruit fly in melon than threefold applications of only chlorpyrifos/cypermethrin during the growing season. The effect of cypermethrin on different stages of melon fruit fly and effect on fecundity and fertility of melon fruit fly has been studied by Rana *et al.* (2015) which provides evidential support to this study. Effective pest control by Jholmol revealed effective management of melon fruit fly using locally available, cheap source material alone with safeguarding environmental and human health. The effective control of melon fruit fly using jholmol has been well reported by Sapkota *et al*. (2010). The effective control of Jassid using Jholmol has been well documented in the study conducted by Bhandari *et al*. (2022), in cowpea against cowpea aphid by Dhakal *et al*. (2018). All these evidences support the relevance of the current study in managing melon fruit fly (*Bactrocera cucurbitae*) in the field condition. This research will provide a baseline for the future studies to be conducted for the effective management of *B. cucurbitae.*

Conclusion

An integrated pest management approach consisting of rational and judicious use of pesticides along with mulching can be a promising approach towards judicious management of *Bactrocera cucurbitae* and improving yield at the same time. Different pesticides used during the experiment resulted promising control against melon fruit fly (*Bactrocera cucurbitae).* Treatment combination of Black plastic mulch + Spinosad or Cypermethrin or Jholmol gave satisfactory control for melon fruit fly in field condition. The use of botanicals; jholmol provided satisfactory control against melon fruit fly under mulching condition. Although a high pest control was observed under mulching condition with pesticide spray of Spinosad and Cypermethrin, Jholmol provided competitive advantage on being cheap & locally available and being safe to environment and human health. Production on mulching along with pesticides resulted superior yield than the non-mulching condition. This suggests the use of black plastic mulch along with pesticides for better control of melon fruit fly and better crop protection.

Conflict of Interest

The authors declare that there is no conflict of interest with this publication.

Authors' Contribution

Pramod Gyawali conducted the research, collected field data and analysed the data using R studio. Pramod Gyawali, Bharat Saud, Sujana Lohani and Babi Kumari Mahato drafted the manuscript and conducted thorough review of the manuscript, Assistant Prof. Sunita Panthi guided the whole research, manuscript preparation, and review of the manuscript. The final version of manuscript was approved by all authors for publication.

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