# EVALUATION OF FIVE BIO-RATIONAL PESTICIDES AGAINST *Bactrocera cucurbitae* (COQUILLETT) IN BITTER GOURD FIELD AND THEIR RESIDUAL EFFECT ON *Coccinella septempunctata* (L.) IN LABORATORY CONDITIONS

**ATHESIS**

**BY**

**MD. ARIF HASNAT**

**REGISTRATION NUMBER: 2205087**

**SEMESTER: JULY-DECEMBER, 2023**

**MASTER OF SCIENCE (M.S.)**

**IN**

**ENTOMOLOGY**

**DEPARTMENT OF ENTOMOLOGY**

**HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY, DINAJPUR-5200**

**DECEMBER, 2023**

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**A Thesis**

*Submitted to the Department of Entomology,*
*Hajee Mohammad Danesh Science and Technology University, Dinajpur in partial fulfillment of the requirements for the degree of*

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**HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY, DINAJPUR-5200**

**DECEMBER, 2023**

*Dedicated*

*To*

*My Beloved Parents and sister*

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*The author*

# ABSTRACT

The cucurbit fruit fly (*Bactrocera cucurbitae* Coquillett) is one of the most important and devastating insect pests for several cucurbits. Biopesticides are an ecofriendly manner to minimize the infestation caused by insect pests. To evaluate the efficacy of five selected biopesticides viz. Ecomec 1.8 EC (Abamectin), Sunmectin 1.8 EC (Abamectin), Lumectin 10 WDG (Emamectin benzoate and Lufenuron), Tracer 45 SC (Spinosad), Green Meta (*Metarhizium anisopliae*) and control against cucurbit fruit fly on bitter gourd were studied from January to June 2023 with consecutive three sprays. The experiment was designed with Randomized Complete Block Design (RCBD) and replicated thrice. The data on the number and weight of healthy and infested fruits and the number of maggots inside the infested fruits were collected. Residual effects on *Coccinella septempunctata* in the laboratory conditions was also performed. The result showed that all the treatments had different levels of infestation reduction and significantly differed from control. The lowest percent of fruit infestation (16.20%, 10.44% and 10.44%) and the highest percent infestation reduction over control (68.75%, 84.39% and 85.33%) were found when applied Tracer 45 SC (Spinosad) after 7 days of 1$^{st}$, 2$^{nd}$ and 3$^{rd}$ spray, respectively. Spinosad also showed the highest weight of healthy fruits (0.0426, 0.621 and 0.776 kg plot$^{-1}$) and the lowest percent infestation by weight (11.12, 6.15 and 5.66%) in all the 3 consecutive picking after 1$^{st}$, 2$^{nd}$ and 3$^{rd}$ spray. The cumulative yield was found the highest (1.832 kg plot$^{-1}$) with 3.62 times increase over the control when applied Tracer 45 SC (Spinosad). The number of maggots inside the infested fruits was also found the lowest (2.33) in Tracer 45 SC treated plot and the highest (6.67) in the control plot. In the case of residual effect on *C. septempunctata* in the laboratory conditions, Sunmectin 1.8 EC (Abamectin) had the longest residual effect on adults of *C. septempunctata* causing 20% mortality at 7 days after treatment (DAT), but low toxicity against fruit fly. However, Green Meta (*M. anisopliae*) (0.00%) had the shortest residual effect on adults of *C. septempunctata* followed by Tracer 45 SC (Spinosad) at 3 DAT. Therefore, Tracer 45 SC (Spinosad) and Green Meta (*M. anisopliae*) can be used for the management of cucurbit fruit flies for their higher efficacy against fruit fly and lower residual activity against *C. septempunctata*.

**Keywords:** Cucurbit fruit fly, biopesticides, bitter gourd, infestation, residual effect.

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# CHAPTER I

# INTRODUCTION

## Background of the study

The soils and climate of Bangladesh are suitable for growing vegetables, and there are many different varieties grown by the farmers. The bitter gourd (*Momordica charantia* Linnaeus) is one of the most important cucurbitaceous summer vegetables and a favorite to all classes of people in Bangladesh and Asia (Khan *et al*. 2019). The growers are encouraged to cultivate bitter gourd on a large scale for its excellent market value and medicinal importance. The total production is 54,443 metric tons from 26,491 acres of land (BBS 2020). In addition to playing a crucial role in a healthy diet for people, it also helps poor farmers by providing a source of money. According to Dhillon *et al*. (2005), the chemical "Charantin" is found in bitter gourds which can reduce blood sugar levels in diabetes patients.

However, the production of bitter gourd is hampered by several of factors, including diseases and insect pests. *Bactrocera cucurbitae* (Coquillett), a cucurbit fruit fly, is one of the insect pests that have been found infesting several cucurbits. It is a major pest that affects 15 different varieties of cucurbit vegetables (Rakshit *et al.* 2011). It can reduce bitter gourd yields by 30% to 100% when susceptible varieties and suitable environmental conditions are present (Dhillon *et al*. 2005). It is reported that the pests are the main limiting factor that severely reduces both the quality and quantity of bitter gourd production (Barnes *et al*. 2004, Biswas *et al.* 2007). The cucurbit fruit fly is an extremely active flying insect, and females typically lay their eggs on soft, sensitive fruit tissues. The eggs develop inside the fruit into maggots (worms), which consume the fruit's pulp and create tunnels in the fruit. The infested fruit starts to decay, dries out and eventually sheds early from the plant. According to Sapkota *et al.* (2010), cucurbit fruit flies infest 41–95% of the fruit in bitter gourd crops. The effective crop management of fruit flies is essential for successful cultivation and the high market value of cucurbit fruits.

However, different management practices with a good degree of work have been reported to control cucurbit fruit fly (Dhillon *et al.* 2005, Mukherjee *et al.* 2007, Islam *et al.* 2015, Bachchu *et al.* 2017, Rahman *et al.* 2019) but some of them either fail to control the pest and are uneconomic, hazardous to non-target organisms and the environment (Dhillon *et al.* 2005). Currently, farmers are applying different types of chemical insecticides to control cucurbit fruit flies. In some areas of Bangladesh, the farmers spend about 25% of the cultivation cost in bitter gourd production only to buy synthetic pesticides (Nasiruddin *et al.* 2004). Management of this pest is also difficult because of its internal feeding behavior. But still, now chemical insecticides are the best weapon for combating different types of notorious pests and synthetic insecticides have been used effectively in controlling melon fruit flies in cucumber and bitter gourd (Oke 2008). But irrationally use of broad-spectrum synthetic insecticides causes potential threats to human being and their environments, at the same time beneficial organisms including insect predators (ants, coccinellid beetle and green lacewings) and parasitoids (wasp)are reduced and other contemporary hazardous are found in the ecology. (Saxena 2008, Simon-Delso *et al.* 2015).

Therefore, it is urgently necessary to do thorough research on the potential use of various safe insecticides and biopesticides. Biopesticides are biological substances or products derived from plants or microorganism that reduce the number of harmful organisms in ecosystems (Salma and Jogen 2011). Additionally, they are thought of as products with a low danger of harming people or the environment. Due to their lack of phytotoxicity, and little or no residues on the environment, biopesticides should be incorporated into Integrated Pest Management (IPM) programs to make them more sustainable (Bhattacharyya *et al.* 2016). Applications of different bio-rational insecticides were reported to be effective for controlling cucurbit fruit flies. Bhowmik *et al.* (2014) represent a result of the lowest percent fruit infestation (8.63%) with the treatment of Spinosad. Rahman *et al.* (2019) also found the percent fruit infestation (20.21%) while treated with Spinosad.

The use of bio-pesticides for the management of cucurbit fruit flies is however a recent approach without any adverse effects on the environment and also has drawn the special attention of the researchers and farmers of Bangladesh and abroad.

Abamectin is a mixture of two homologues containing >80% of avermectin B and <20% of avermectin B1b (Pozo *et al.* 2003). The bio-pesticide abamectin has been used to control a large variety of insects, including Diptera species and attributed to its high toxicity with virtually no residual effects on treated crops (El-Gendy *et al.*2021). Its low residual effect ensures the survival of natural enemies and other non-target organisms.

Emamectin benzoate is a novel macrocyclic lactone insecticide derived from naturally occurring avermectin molecules isolated by fermentation from the soil microorganism *Streptomyces avermitilis* and it is considered a valuable tool for the control of codling moth as a component of an IPM programme (Ioriatti *et al.* (2009). Dash *et al.* 2020) reported that Emamectin benzoate 5% SG at 17.0 g a.i $ha^{-1}$ was found most effective against shoot and fruit borer with an average reduction of 90.72% in population after three sprays on okra fruits and the highest yield (8.29 t $ha^{-1}$) was obtained from Emamectin benzoate 5% SG at 17.0g a.i $ha^{-1}$. Nisar *et al.* (2020) reported that lufenuron has chemosterility impacts on both male and female peach fruit flies (*B. zonata)* when treated with a baited diet and found that mortality in adults increased, egg hatchability and fecundity decreased. Nehra *et al.* (2019) found that spinosad was found most effective insecticide evaluated against fruit fly, *B. cucurbitae* (Coquillett) on the gourd and the maximum marketable yield of round gourd fruits was obtained in spinosad (105.14 q $ha^{-1}$) followed by acephate + molasses (102.57 q $ha^{-1}$). Yee *et al.* (2006) reported that spinosad showed higher mortality in laboratory conditions and prevented oviposition of adult cherry fruit fly (Diptera: Tephritidae) than imidacloprid and also showed greatest residual toxicity on leaves, killing 100% of adults. Biopesticides are safe to use since pre-harvest intervals for fresh fruits and vegetables (Khater 2012). They are also target-specific, which means they don't kill beneficial creatures like natural enemies.

Therefore, considering all these facts, the present investigations were undertaken to evaluate the efficacy of one hepatoprotective agent (abamectin), one fungal (Green Meta) and three bacterial fermented (abamectin, spinosad and emamectine benzoate and lufenuron) bio-pesticides against the cucurbit fruit fly, *B. cucurbitae* on bitter gourd and their residual effect on *Coccinella septempunctata*in (L.) the laboratory conditions.

**Research objectives:**

The present study was conducted with some ecofriendly biopesticides against cucurbit fruit fly in the field and lady bird beetle in the laboratory. From this view of point, the present study was undertaken

1. To evaluate the efficacy of selected bio-pesticide against cucurbit fruit fly on bitter gourd field.
2. To find out the effect of bio-pesticides on the yield of bitter gourd.
3. To find out the residual effect of the bio-pesticides on *C. septempunctata* in laboratory conditions.

# CHAPTER II

# REVIEW AND LITERATURE

Bitter gourd (*Momordica charantia*) cucurbitaceous vegetables are highly prone to damage by cucurbit fruit fly, *Bactrocera cucurbitae* (Coquillett). Cucurbit fruit fly is a most important and destructive pests of many crops but there are many difficulties associated with the management of this pest. The literatures on the use of different types of bio-pesticides against fruit fly have been reviewed under the following sub-headings:

## 2.1 Systemic position of cucurbit fruit fly

Phylum: Arthropoda
Class: Insecta
Sub-class: Pterygota
Division: Endopterygota
Order: Diptera
Sub-order: Cyclorrhapa
Family: Tephritidae
Genus: *Bactrocera*
Species: *Bactrocera cucurbitae* (C.)

## 2.2 Synonyms

The synonyms of *Bactrocera cucurbitae* (Coquillett) are known to:

i) *Chaetodacus cucurbitae*

ii) *Dacus cucurbitae*

iii) *Strumeta cucurbitae*

## 2.3 Host ranges

Vegetables, oil seeds, fruits, and ornamental plants are seriously damaged by variety of fruit fly species. Ten cucurbit vegetables were identified by Alam (1969) as the host of the fruit fly in Bangladesh.

Doharey (1983) reported that it infests over 70 host plants, amongst which, fruits of bitter gourd (*M. charantia*), muskmelon (*Cucumis melo*), snap melon (*Cucumis melo* var. *momordica*) and snake gourd (*Trichosanthes anguina* and *T. cucumeria*) are the most preferred hosts.

Tomato, green pepper, papaya, cauliflower, mango, guava, citrus, near fig and peaches are also infested by fruit fly (Atwal 1986, Anon. 1988).

Fruit flies are attracted by sixteen types of plants, and *B. cucurbitae* and *B. tau* both chose the sweet gourd as a host whereas bottle gourd had worse infestation intensity (Kabir *et al.* 1991).

Batra (1953) mentioned as many as 70 hosts for different fruit fly species while Christenson and Foote (1960) reported more than 80 different types of vegetables and fruits were the hosts of these pests.

Kapoor (1993) reported that more than 100 vegetables and fruits are attacked by *Bactrocera sp*. Atwal (1986) and Mckinlay *et al.* (1992) reported that cucurbits as well as 70-100 non-cucurbitaceous vegetables and fruits are the host of fruit fly.

### 2.4 Nature of damage

The development of brown resinous coatings on fruits was reported by Shah *et al.* (1948) and York (1992) as an indication of infection. On fruits or vegetables, the insertion of ovipositor results in puncture wounds. Through frass contamination and pathogenic infection, the larvae cause indirect damage to the fruits by accelerating their rotting. If the fruit is infected but not yet rotting, it will develop deformed and hardy and become unfit for consumption. The fly also attacks flowers and the infested flowers often become juicier and drop from the stalk at slight jerk (Kabir *et al.* 1991). According to Kapoor (1993), some flies make mines and a few form galls on different parts of the plants. Singh (1983) reviewed that the maggots bore and feed inside the fruits causing sunken discolored patches, distortion and open cracks. Affected fruits prematurely ripe and drop from the plants. The cracks on fruits serve as the predisposing factor to cause pathogenic infection resulting in decomposition of fruits. Amin (1995) and Uddin (1996) observed 42.08% and 45.14% fruit fly infestation in cucumber, respectively.

**2.5 Life history of fruit**

The *B. cucurbitae* lays eggs inside the fruit that are 1.3 mm long, oblong, creamy white in color, and banana-shaped (Anon. 1988). The lower and upper developmental thresholds for eggs were 11.4 and 36.4° C (Messenger and Flitters 1958). In order to shelter them from the sun, eggs are typically placed under the skin of fruits, vegetables, nuts, or fleshy portions of plants, stems, or flowers (Feron *et al.* 1958). When the maggots hatch from the eggs, they begin to feed inside. The majority of fully developed larvae quickly penetrate into the ground and pupate below the soil surface. The larval period lasts between 4 and 7 days, depending on the temperature, nutritional status, density of larval rearing, etc. (Anon. 1988). According to Christenson and Foote (1960), pupal formation is finished within the puparium in less than 48 hours, and puparium formation can take less than as an hour. The larvae spend their fourth instars in the puparium created by their third instar exuviae, where they turn into pupae. The puparium is a length of 4.8 to 6.0 mm. The pupal stage lasts 8–12 days at 23–25 °C. The mean pupal time for *B. cucurbitae* is 9 days at 27 °C, compared to 10 days for *B. dorsalis* and *Ceratitis capitata* (Wiedemann) (Mitchell *et al.* 1965). Mating between the adult melon fruit flies generally takes place at about dusk and last for about an hour or more (Narayan and Batra 1960). Mating starts in the evening and continues till dawn. Melon Flies may mate every 4-5 days. Females found to lay eggs up to 7-10 days. Eggs are laid 7-10 per female per day. In her lifetime, a female melon fly can produce 800-900 eggs, with a fertility rate of about 50% (Vargas *et al.* 1984). According to Janjua (1948) the pre-oviposition period of *B. ferrugeneus* is two to five days but it may range from 10 to

15 days or longer in varying conditions of climate and diet. Life cycle is completed in 10 to 18 days but it takes 12 to 13 weeks in winter. Adult longevity is 2 to 5 months; females live longer than males. Generally, males die soon after fertilizing the females, whereas, females die later. Nair (1986) reported that the flies, which emerge in the morning hours, oviposit for four days in autumn and 9 to 30 days in winter. Adults begin to copulate 9-12 days after emergence and the longevity of adult fly is 1 to 5 months in the laboratory and under the optimum condition, the length of one generation is around 1 month (Anon 1988).

**2.6 Management of fruit**

Among all the damaging factor of cucurbits fruit fly is the most dangerous one over the world. Various methods are available to combat against this pest but is not a single such method which has so far been successfully reduced the damage of fruit fly. The main reason is the polyphagous nature of these pests that helps them to build up population year-round. The available literatures on the measures for the controlling of these flies with bio-pesticides and pyrethroids are discussed under the following sub-headings:

**2.7 Sunmectin 1.8 EC, Ecomec 1.8 EC (Abamectin 1.8%)**

Abamectin belongs to the family of avermectins, a class of macrocyclic lactonesproduced by a soil actinomycete, Strep-tomices avermitilis. Abamectin is a mixture of two homologues containing >80% of avermectin B and <20% of avermectin Blb (Pozo *et al.* 2003).

El-Gendy *et al.* (2021) stated that the bio-pesticide abamectin has been used to control a large variety of insects, including Diptera species, attributed to its high toxicity with virtually no residual effects on treated crops. Its low residual effect ensures the survival of natural enemies and other non-target organisms.

Babu *et al.* (2002) reported high efficacy of abamectin against *B. cucurbitae* on watermelon. Albrecht and Sherman (1987) also reported high toxicity and reproductive inhibitory effect of abamectin against Mediterranean fruit fly, *C. capitata*, Oriental fruit fly, *B. dorsalis* and melon fruit fly *B. cucurbitae*.

Khursheed and Raj (2012) found that Abamectin was the most effective treatment in terms of reducing the fruit infestation as well as number of maggots due to presence of anti-oviposition effect of abamectin against the melon fruit fly, *Bactrocera spp*.

Thonghua (2015) reported that the use of abamectin 1.8% EC at 15-20ml/20L water with 4-time spraying had the highest effectiveness in the management of Pomelo fruit fly.

**2.8 Lumectin 10 WDG (Emamectin benzoate & Lufenuron)**

Emamectin benzoate is a novel macrocyclic lactone insecticide derived from naturally occurring avermectin molecules isolated by fermentation from the soil microorganism *Streptomyces avermitilis* and it is considered as a valuable tool for the control of codling moth as a component of an IPM programme (Ioriatti *et al.* 2009).

Ioriatti *et al.* (2009) also reported that Emamectin benzoate was highly active against both *Cydia pomonella* and *C. molesta* neonate larvae when it was ingested during fruit entry. *C. pomonella* larvae are able to feed on fruit and cause visible damage before being killed by the toxic effect, while *C. molesta* larvae were immediately affected by the toxicity of the product and died without causing any damage to the infested fruit.

Dash *et al.* (2020) reported that Emamectin benzoate 5% SG at 17.0g a.i $ha^{-1}$ were found most effective against shoot and fruit borer with an average reduction of 90.72% in population after three sprays on okra fruits and the highest yield (8.29 t $ha^{-1}$) was obtained from Emamectin benzoate 5% SG at 17.0g a.i $ha^{-1}$

Khanal *et al.* (2021) found that Emamectin benzoate was the most effective treatment for the management of brinjal shoot and foot borer (*Leucinodes orbonalis*) at the lowest percentage of infested fruit i.e., 57.97% and 34.52% and the marketable yield found the highest from the treatment of Emamectin benzoate.

**2.9 Tracer 45 SC (Spinosad)**

Spinosad is the first active ingredient in the naturalize class of insect control products that introduced by Dow Agro Science with the trade name of Tracer. Spinosad is a naturally occurring mixture of two active components, spinosyn A and spinosyn D produced by the soil actinomycete *Saccharopolyspora spinosa*. (Salgado 1998).

According to Nehra *et al.* (2019), spinosad was the insecticide most effective against the fruit fly, *Bactrocera cucurbitae* (Coquillett), on round gourds and spot the highest marketable yield of round gourd fruits (105.14 q ha-1), followed by acephate + molasses (102.57 q ha-1), and the lowest (50.12 q ha-1).

Yee *et al.* (2006) reported that spinosad showed the higher mortality in laborary condition and prevented oviposition of adult cherry fruit fly (Diptera: Tephritidae) than imidacloprid and also showed greatest residual toxicity on leaves, killing 100% of adults.

**2.10 Green Meta *(Metarhizium anisopliae*):**

Sookar *et al.* (2014) stated that the entomopathogenic fungus, *Metarhizium anisopliae* (Metchnikoff) Sorokin (Hypocreales: Clavicipitaceae), which was isolated from the soils of Mauritius, was used to investigate whether fungus-treated adult fruit flies could transfer conidia to non-treated flies during mating, and whether fungal infection could have an effect on mating behavior, fecundity, and fertility of the two female fruit fly species.

Sookar *et al.* (2014) found that infection by *M. anisopliae* did not only result in mortality of fruit flies, but also resulted in the reduction of the number of eggs produced by females of *B. cucurbitae* from 30 ± 1 eggs/untreated female to 15 ± 6 eggs/treated female.

Male and female donors of *B. zonata* and *B. cucurbitae* exposed directly to conidia of *M. anisopliae* became infected and all died of fungal infection within six to seven days postexposure. (Sookar *et al.* 2014).

*Metarhizium anisopliae*, previously reported to be pathogenic to the two species of fruit flies (Sookar *et al.* 2008).

Castillo *et al.* (2000) obtained 65% reduction in fecundity of the Mediterranean fruit fly treated with *P. fumosoroseus* and 40–50% reduction with *M. anisopliae* and *A. ochraceus*.

# CHAPTER III

# MATERIALS AND METHODS

## 3.1 Experimental site

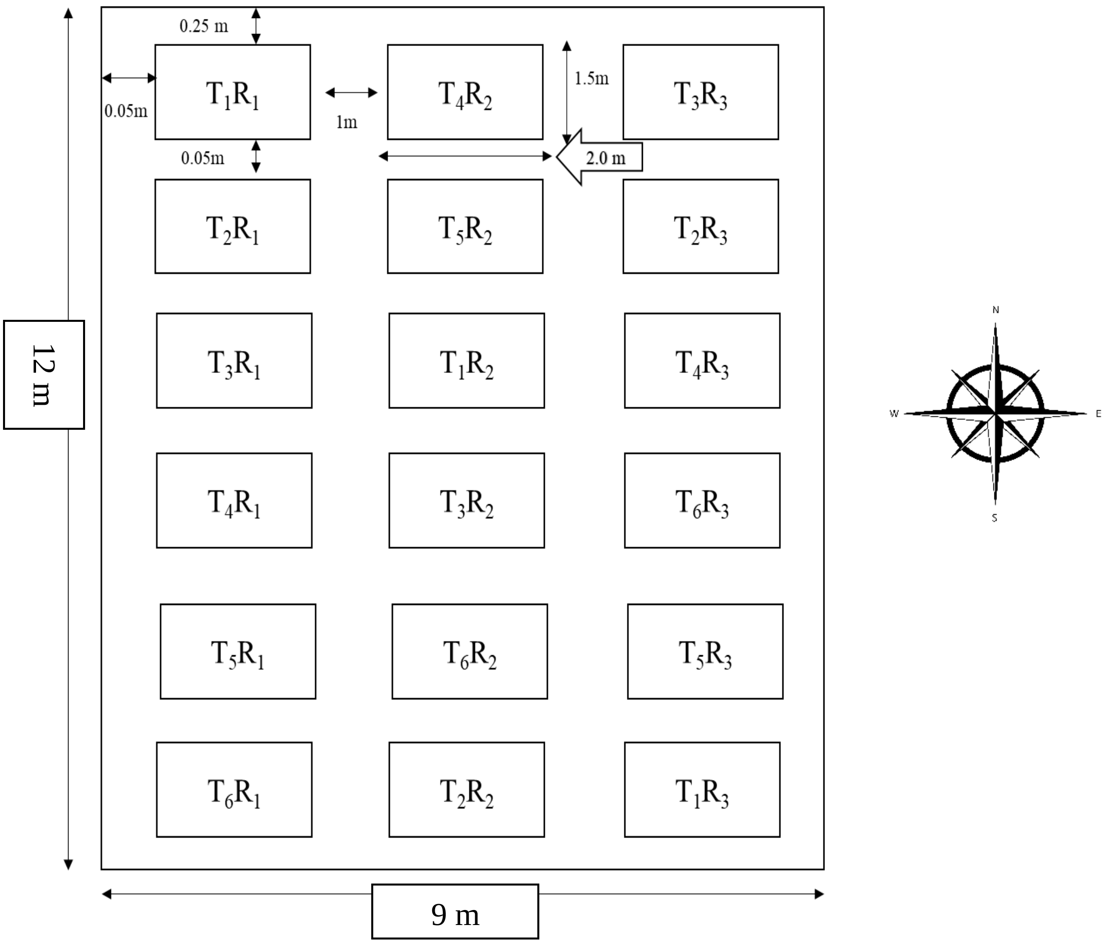
The study was conducted to evaluate five bio-rational pesticides against *Bactrocera cucurbitae* (Coquillett) in bitter gourd field and their residual effect on *Cocccinella septempunctata* (L) in the research field and the laboratory of Entomology Department, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur during of January to June 2023.

## 3.2 Tested biopesticides

The tested biopesticide (treatments) in the present study are listed in Table 1 with their chemical and trade names, active ingredients, recommended dose and manufacturers. Five different biopesticides that were selected to evaluate the field efficacy against cucurbit fruit fly in bitter gourd (Plate 1) All these biopesticides were collected from the local dealer shop in the local market of Dinajpur, Bangladesh.

## 3.3 Preparation of land and layout of the experiment

The field experiment was prepared by deep ploughing and harrowing followed by laddering. All weeds and stubble were removed from the field during land preparation. Finally, 10 cm raised bed plots were made along with the addition of the basal doses of manures and fertilizers. According to Nasreen *et al.* (2013), cow dung, N, P, K, and S were treated at the rates of 5 t, 120, 40, 80, and 30 kg per hectare, respectively. During land




| | |
|---|---|
| Total plot area | : 108 $m^2$ |
| Design | : RCBD |
| Treatments | : 6 |
| Replication | : 3 |
| Total number of plots | : 18 |
| Unit plot size | : 2.0 m x 1.5 m |
| Plot to plot distance | : 0.50 m |
| Block to block distance | : 1.0 m |
| Total field size | : 12 m x 9 m |
| Plot to boundary distance (Breadth) | : 0.25 m |
| Plot to boundary distance (length wise) | : 0.50 m |

| **Treatments** | | Dose/L of water |
|---|---|---|
| $T_1$ | : Ecomec 1.8 EC (Abamectin 1.8%) | 1ml/L |
| $T_2$ | : Sunmectin 1.8 EC (Abamectin 1.8%) | 1.20ml/L |
| $T_3$ | : Lumectin 10 WDG (Emamectin benzoate and Lufenuron) | 1.0 gm/L |
| $T_4$ | : Tracer 45 SC (Spinosad) | 0.50 ml/L |
| $T_5$ | : Green Meta (*Metarrhizium anisoplae*) | 10.0ml/L |
| $T_6$ | : Control | |

**Fig 1:** Field layout of the experiment with randomized complete block design.

preparation, total amount of cow dung, two-thirds of TSP, and one-third of urea were applied as a base dose. The remaining TSP and half of the MP were applied in the pits before seven days of seed sowing. The experiment was conducted in a Randomized Complete Block Design (RCBD) with 6 treatments and 3 replications. The total experiment land was divided into 18 plots equally by 2.5 m × 2.0 m of each plot. The plot-to-plot distance was 0.50 m and the block-to-block distance was 1.0 m. The whole experimental field was 15.0 m (length) × 10 m (breath) which was divided into 3 equal blocks. In the center of each plot, 30 cm x 30 cm x 20 cm pits were dug for sowing seeds of bitter gourd. Each pit was considered as one replication.

### 3.4 Collection and sowing of seeds, and intercultural operations

Bitter gourd seeds (Tia) were collected from Lal Teer Seed Company, Dhaka. The seed was soaked in water for 24 hours in the Petri dishes before sowing to soften the seed coat for better and quick germination. Two seeds per pit were sown directly. Before sowing, the seeds were treated with Vitavax 200 @ 2 g per kg of seed. After seeding, irrigation was performed as needed. Finally, each pit contained only one healthy plant. A new seedling was replaced instead of the damaged and sick ones. The bamboo stick was used for each of the seedlings to support it. The other intercultural operations were done for each of the seedlings in the field.

### 3.5 Application of treatments and data collection

All the bio-pesticides were applied to the bitter gourd plots after the fruit's initiation at the recommended doses by hand sprayer (model Ca: 2L). Data on the number of healthy and infested fruits for each treatment were collected 1 day before, 3 and 7 days after treatment (DAT). A total number of three sprays were applied at 10-day intervals (starting from fruit initiation to before maturity). The fruits were picked thrice on 8th day after the application of the treatments. Before and after the treatment's application. healthy, infested and the total number of bitter gourd fruit was counted from each plot. After every picking, the number and weight of healthy and infested fruit were also measured. Healthy or marketable fruits of bitter gourd (Plate 2) were defined as the fruits having no hole, no deformation, or no pseudo-puncture present on the fruits. The number of maggots inside the infested fruits (Plate 2) was also counted by sectioning the fruits from each of the plots.

### 3.6 Percent fruit infestation as number

After harvesting, the healthy fruit (HF) and the infested fruits (IF) were separated by visual observation. The percent fruit infestation for each treatment was calculated by using the following formula given by Bachchu *et al*. (2017).

% Fruit infestation by number = Number of IF/ (Number of HF + Number of IF) × 100

### 3.7 Percent fruit infestation as weight

After sorting the healthy and the infested fruits, the weight was taken for the healthy, infested and total ones separately. The percent infested fruits as the weight for each treatment was calculated by using the following formula given by Bachchu *et al*. (2017).

% Fruit infestation by weight = Weight of IF/ (Weight of HF + Weight of IF) × 100

### 3.8 Increase of marketable yield (times) over control

The increase of marketable yield (times) due to the application of different treatments over control was calculated by the following formula given by Khatun *et al.* (2015)

Increase of marketable yield (times) over control= Cumulative yield in treated plot (Yt) / Cumulative yield in control plot (Yc).

### 3.9 Percent reduction of fruit infestation over control

The calculation of percent fruit infestation reduction over control was done by following the formula given by Ali *et al.* (2022)

% Reduction over control = (Infestation percent in control – infestation percent in treatment)/ infestation percent in control × 100

### 3.10 Residual toxicity assessment of *C. septempunctata* adults

For conducting residual effects of bio-pesticides on *C. septempunctata* adults, the selected bio pesticides and water were sprayed separately inside the Petri dishes. The lids of Petri dishes (6 D × 1 H cm) were also sprayed in the same manner. Afterward, five-day-old adults of *C. septempunctata* were released in individual Petri dishes and covered with a perforated lid, including water spray in case of control. Thirty adults of *C. septempunctata* were used for each treatment. Mortality data was counted after 24 hours of exposure. A similar procedure was performed on 3 and 7 days.

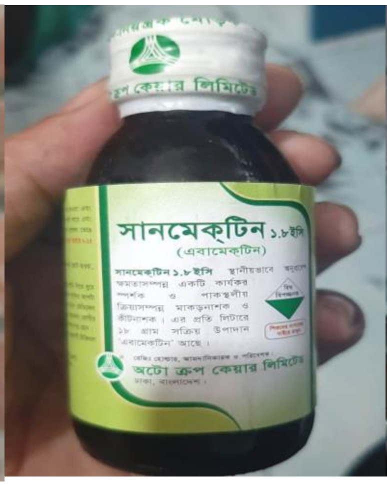
### 3.11 Statistical analysis

All the obtained data were analyzed by following the analysis of variance (ANOVA) technique with the help of statistix 10 program and the mean differences were adjusted by the Least Significant Difference (LSD) method. All graphical works were done through Microsoft Excel (version 16) program.

**Table 1:** List of biopesticides with chemical and trade names, their types, active ingredients contents, recommended doses and the manufacturers applied in the study.

| Chemical name | Trade name | Active ingredients | Recommended dose/L of water | Company name |
|---|---|---|---|---|
| $C_{35}H_{44}O_{16}$ | Ecomec 1.8 EC | Abamectin 1.8% | 1.0 ml | Ispahani Agro Ltd. |
| $C_{48}H_{75}O_{14}$ | Sumnectin 1.8 EC | Abamectin 1.8% | 1.20 ml | Auto Crop Care Ltd. |
| $C_{49}H_{75}NO_{13}$ | Lumectin 10 WDG | Emamectin and benzoate Lufenuron | 1.0 gm | Haychem (Bangladesh) Ltd. |
| $C_{41}H_{65}NO_{10}$ | Tracer 45 SC | Spinosad | 0.50 ml | Auto Crop Care Ltd. |
| | Green Meta | Green muscardine Fungus spore *Metarhizium anisopliae* | 10.0 ml | Green Life Biotech Laboratory, India |
| --- | Control | --- | --- | --- |


Ecomec 1.8 EC




Sunmectin 1.8 EC


Lumectin 10 WDG


Tracer 45 SC


Green Meta

*(Metarhizium anisopliae)*


Pneumatic hand and sprayer 2 L

**Plate 1 :** Different Biopesticides and Hand Sprayer

Healthy fruit and marketable fruits

Infested fruit

Maggots inside the infested fruits

**Plate 2:** Healthy and marketable fruits, infested fruit and maggots inside the infested fruits.

# CHAPTER IV

# RESULTS AND DISCUSSION

The efficacy of selected biopesticides were evaluated against fruit fly, *Bactrocera cucurbitae* (Coquillett) in the field experiment and the residual effect of the biopesticide on *Coccinella septempunctata* was studied in the laboratory. The results and discussion of the study under different parameters are presented below with the following titles:

## 4.1 Efficacy of selected biopesticides on the percent fruit infestation caused by *Bactrocera cucurbitae* 1 day before and, 3 and 7 days after 1$^{st}$ spray

The efficacy of applied biopesticide on the percent fruit infestation by number caused by *B. cucurbitae* 1 day before and, 3 and 7 days after 1$^{st}$ spray with percent reduction of infestation over control plot are presented in Table 2. One day before 1$^{st}$ spray the percent of fruit infestation by number was not significantly different ($F$=0.2, $df$=5, $P$>0.05) (Appendix Table 1) among the treatments. The percent fruit infestation was observed to decrease after 3 and 7 days of 1$^{st}$ spray where significantly lowest (22.54% and 16.20%, respectively) fruit infestation were observed when applied Tracer 45 SC (Spinosad). Tracer 45 SC (Spinosad) was found the highest (68.75%) percent reduction of infestation over control followed by Green meta (55.12%) and Ecomec 1.8 EC (51.47%). Bhowmik *et al.* (2014) represent a result of the lowest percent (8.63%) fruit infestation at 7 days after of 1$^{st}$ spraying with the treatment of Spinosad which is more or less close to our result. Rahman *et al.* (2009) also found that the percent fruit infestation was 20.21% while treated with Spinosad after 3 days of 1$^{st}$ spray and the result is approximate to the current findings.

### 4.2 Efficacy of selected biopesticides on the percent fruit infestation caused by *B. cucurbitae* 1 day before and, 3 and 7 days after 2nd spray

Table 3 shows the efficacy of applied biopesticide on the percent fruit infestation by number caused by *B. cucurbitae* 1 day before and 3 and 7 days after 2nd spray with a percent reduction of infestation over control plot. One day before 2nd spray percent fruit infestation by number was not significantly different ($F$=2.50, $df$=5, $P$>0.05) (Appendix Table 2) among all the treatments. The percent fruit infestation was observed to decrease after 3 and 7 days of 2nd spray where significantly lowest (13.23% and 10.44%, respectively) fruit infestations were recorded in Tracer 45 SC (Spinosad). Tracer 45 SC (Spinosad) was found the highest (84.39%) percent reduction of infestation over control followed by Green meta (68.95%) and Lumectin1.8 EC (Abamectin) (63.34%). Bhowmik *et al.* (2014) also described that the lowest percent of fruit infestation (6.24%) was found after 7 days while using Spinosad. Rahman *et al.* (2019) showed that 3 DAS of 2nd spray the percent fruit infestation of Spinosad was 12.94% which is almost similar to the present study.

### 4.3 Efficacy of selected biopesticides on the percent fruit infestation caused by *B. cucurbitae* 1 day before and, 3 and 7 days after 3rd spray

The percent fruit infestation one day before 3rd spray and 3 and 7 days after the spray and reduction of infestation over the control is represented in Table 4. One day before 3rd spray percent of fruit infestation by number was significantly different ($P$<0.05, $F$=6.25, $df$= 5) (Appendix Table 3) among all the treatments. One day before the 3rd spray the highest (63.89%) fruit infestation was observed in the control but the lowest (30.55%) fruit infestation was found in treated plot of Tracer 45 SC (Spinosad). The percent fruit infestation was observed to decrease after 3 and 7 days of 3rd spray where significantly the lowest (12.27% and 10.44%, respectively) fruit infestation were observed when applied treatment Tracer 45 SC (Spinosad) in the plot. Tracer 45 SC (Spinosad) treated plot was shown the highest (85.33%) percent reduction of infestation over control plot followed by Lumectin 10 WDG (67.82%) and Green Meta (63.33%) treated plot. Bhowmik *et al.* (2014) found that after 7 days of 3$^{rd}$ spray, Spinosad performed the lowest percent infestation (2.54%) which was lower than the current finding.

**Table 2:** Efficacy of selected biopesticides on the percent fruit infestation (by number) caused by *B. cucurbitae* 1 day before and, after 3 and 7 days of 1st spray.

| Treatments | % Fruit infestation (by number) | | | | % Reduction over control |
|---|---|---|---|---|---|
| | 1 DBS[1] | 3 DAS[2] | 7 DAS[2] | Cumulative mean of 3 & 7 DAS[2] | |
| Ecomec 1.8 EC (Abamectin) | 44.44 ± 5.56 a | 35.55 ± 2.22 b | 24.60 ± 3.97 cd | 30.07 ± 0.87 b | 51.47 |
| Sunmectin 1.8 EC (Abamectin) | 38.88 ± 5.56 a | 31.19 ± 4.52 bc | 29.29 ± 6.94 bc | 30.24 ± 5.73 b | 51.22 |
| Lumectin 10 WDG (Emamectin benzoate and Lufenuron) | 41.67 ± 8.33 a | 36.19 ± 3.81b | 37.14 ± 4.36 b | 36.67 ± 4.07 b | 40.85 |
| Tracer 45 SC (Spinosad) | 44.44 ± 11.11a | 22.54 ± 5.64 c | 16.20 ± 4.42 d | 19.37 ± 5.00 c | 68.75 |
| Green Meta *(Metarhizium anisopilae)* | 41.11 ± 4.84 a | 25.00 ± 4.81bc | 30.63 ± 1.41 bc | 27.82 ± 2.93 bc | 55.12 |
| Control | 36.11 ± 7.35 a | 55.71 ± 2.97 a | 68.26 ± 1.59 a | 61.98 ± 1.85 a | - |
| LSD | 9.81 | 12.60 | 10.89 | 10.28 | - |
| CV | 29.24 | 20.16 | 17.42 | 16.45 | - |
| Level of significance | NS | ** | ** | ** | - |

Mean values within column followed by different letters are significantly different at 5% level of probability by LSD. ± SE indicates standard error, DBS[1]: Days before spray, DAS[2]: Days after spray. ** indicates 1% level of significance and NS= Not Significance

**Table 3:** Efficacy of selected biopesticides on the percent fruit infestation (by number) caused by *B. cucurbitae* 1 day before and, after 3 and 7 days of 2nd spray.

| Treatment | % Fruit infestation (by number) | | | | % Reduction over control |
|---|---|---|---|---|---|
| | 1 DBS[1] | 3 DAS[2] | 7 DAS[2] | Cumulative mean of 3 & 7 DAS[2] | |
| Ecomec 1.8 EC (Abamectin) | 37.77 ± 2.22 b | 30.16 ± 1.59 b | 32.75 ± 2.27 b | 31.46 ± 1.83 b | 58.49 |
| Sunmectin 1.8 EC (Abamectin) | 35.55 ± 2.22 b | 29.52 ± 5.79b | 30.16 ± 1.59bc | 29.27 ± 2.94 b | 60.62 |
| Lumectin 10 WDG (Emamectin benzoate and Lufenuron) | 36.11 ± 7.35 b | 31.74 ± 1.59 b | 23.81 ± 4.76 bc | 27.77 ± 3.17 b | 63.34 |
| Tracer 45 SC (Spinosad) | 27.77 ± 2.78 b | 13.23 ± 1.06 c | 10.44 ± 0.67d | 11.83 ± 0.87 c | 84.39 |
| Green Meta *(Metarhizium anisopilae)* | 38.33 ± 7.27 b | 26.11 ± 3.89 bc | 20.95 ± 4.15c | 23.53 ± 4.02 b | 68.95 |
| Control | 60.00 ± 11.55 a | 70.71 ± 6.94 a | 80.84 ± 3.13 a | 75.78 ± 2.19 a | - |
| LSD | 21.64 | 13.80 | 9.59 | 8.41 | - |
| CV | 30.30 | 22.59 | 15.90 | 13.85 | - |
| Level of significance | NS | ** | ** | ** | - |

Mean values within column followed by different letters are significantly different at 5% level of probability by LSD. ± SE indicates standard error, DBS[1]: Days before spray, DAS[2]: Days after spray. ** indicates 1% level of significance and NS= Not Significance

**Table 4:** Efficacy of selected biopesticides on the percent fruit infestation (by number) caused by *B. cucurbitae* 1 day before and, after 3 and 7 days of 3rd spray.

| Treatment | % Fruit infestation (by number) | | | | % Reduction over control |
|---|---|---|---|---|---|
| | 1 DBS[1] | 3 DAS[2] | 7 DAS[2] | Cumulative mean of 3 & 7 DAS[2] | |
| Ecomec 1.8 EC (Abamectin) | 35.55 ± 2.22 b | 31.19 ± 4.52 b | 26.11 ± 3.89 b | 28.65 ± 3.11 b | 62.97 |
| Sunmectin 1.8 EC (Abamectin) | 32.78 ± 8.33 b | 30.47 ± 6.67 b | 28.06 ± 6.09 b | 29.27 ± 6.31 b | 62.17 |
| Lumectin 10 WDG (Emamectin benzoate and Lufenuron) | 38.33 ± 4.84 b | 23.33 ± 5.09 bc | 26.45 ± 2.12 b | 24.89 ± 3.34 b | 67.97 |
| Tracer 45 SC (Spinosad) | 30.55 ± 2.78 b | 12.26 ± 1.24 c | 10.44 ± 0.67 c | 11.35 ± 0.94 c | 85.33 |
| Green Meta *(Metarhizium anisopilae)* | 35.55 ± 3.33 b | 28.97 ± 2.41 b | 27.78 ± 2.78 b | 28.38 ± 0.79 b | 63.33 |
| Control | 63.89 ± 7.35 a | 75.79 ± 5.51 a | 78.94 ± 2.04 a | 77.38 ± 3.51 a | - |
| LSD | 15.46 | 15.32 | 11.65 | 11.90 | - |
| CV | 21.55 | 25.03 | 19.43 | 19.64 | - |
| Level of significance | ** | ** | ** | ** | - |

Mean values within column followed by different letters are significantly different at 5% level of probability by LSD. ± SE indicates standard error, DBS[1]: Days before spray, DAS[2]: Days after spray. ** indicates 1% level of significance

**4.4 Efficacy of selected biopesticides on the weight of healthy and infested fruits and percent infestation by weight at 1st picking after 1st spray**

The weight of healthy fruits after 1st picking was significantly differed (*F*=9.45=, *df*=5, *P*<0.05) (Appendix Table 4) among the treatments. The highest weight of healthy fruits after 1st picking was recorded in Tracer 45 SC (Spinosad) (0.426 kg $plot^{-1}$) followed by *M. anisopliae* (0.336 kg $plot^{-1}$). But the lowest healthy fruits at 1st picking after 1st spray recorded in control (0.152 kg $plot^{-1}$). (Table 5)

The weight of infested fruits and percent fruit infestation at 1st picking was significantly different (*F*=9.82, *df*=5, *P*<0.05) (Appendix Table 4) among the treatments. The lowest weight of infested fruit (0.053 kg $plot^{-1}$) was recorded in Tracer 45 SC (Spinosad). However, the highest weight of infested fruits at 1st picking after 1st spray was found in control (0.145 kg $plot^{-1}$). The lowest percent infestation by weight (11.12%) was also found in Tracer 45 SC (Spinosad) followed by Green Meta (*M. anisopliae*) (13.82%) and the highest percent infestation by weight (49.84%) was found in control plot. (Table 5)

From the above findings, it was observed that the highest weight of healthy fruits was found in Tracer 45 SC (Spinosad) treated and the lowest was in the control plot. Conversely, the lowest weight of infested fruit was found in Tracer 45 SC (Spinosad) and the highest in the control plot. The percent fruit infestation (by weight) was also the lowest in Tracer 45 SC (Spinosad) treated plot and the highest in the control plot.

**4.5 Efficacy of selected biopesticides on the weight of healthy and infested fruits and percent infestation by weight at 2nd picking after 2nd spray**

Efficacy of selected biopesticide on the weight of healthy, infested fruits and percent fruit infestation after 2nd picking after 2nd spray of bitter gourd. The weight of healthy fruits after 2nd picking was significantly different (*F*=19.40=, *df*=5, *P*<0.05) (Appendix Table 4) among the treatments. The highest weight of healthy fruits (0.621 kg plot$^{-1}$) after 2$^{nd}$ picking was recorded in Tracer 45 SC (Spinosad) followed Lumectin 10 WDG (0.402 kg plot$^{-1}$). But the lowest healthy fruits (0.150 kg plot$^{-1}$) at 2$^{nd}$ picking after 2$^{nd}$ spray were recorded in the control plot. (Table 6)

The weight of infested fruits and percent fruit infestation at 2$^{nd}$ picking was significantly different ($F$=13.34, $df$=5, $P$<0.05) (Appendix Table 4) among the treatments. The lowest weight of infested fruit (0.040 kg plot$^{-1}$) was recorded in Tracer 45 SC (Spinosad). However, the highest weight of infested fruits at 2$^{nd}$ picking after 2$^{nd}$ spray found in control (0.243 kg plot$^{-1}$). The lowest percent infestation by weight (6.15%) was also found in Tracer 45 SC (Spinosad) followed by Lumectin 10 WDG (16.32%) and the highest percent infestation by weight (62.06%) was found in the control plot.

**4.6 Efficacy of selected biopesticides on the weight of healthy and infested fruits and percent infestation by weight at 3$^{rd}$ picking after 3$^{rd}$ spray.**

Efficacy of selected biopesticide on the weight of healthy, infested fruits and percent fruit infestation after 3$^{rd}$ picking after 3$^{rd}$ spray of bitter gourd. The weight of healthy fruits after 3$^{rd}$ picking was significantly different ($F$=13.42=, $df$=5, $P$<0.05) (Appendix Table 4) among the treatments. The highest weight of healthy fruits (0.776 kg plot$^{-1}$) after 3$^{rd}$ picking was recorded in Tracer 45 SC (Spinosad) followed by Ecomec 1.8 EC (Abamectin) (0.485 kg plot$^{-1}$). But the lowest healthy fruits (0.202 kg plot$^{-1}$) at 3$^{rd}$ picking after 3$^{rd}$ spray recorded in control. (Table 7)

The weight of infested fruits and percent fruit infestation at 3$^{rd}$picking was significantly different ($F$=27.01, $df$=5, $P$<0.05) (Appendix Table 4) among the treatments. The lowest weight of infested fruit (0.046 kg plot$^{-1}$) was recorded in Tracer 45 SC (Spinosad). However, the highest weight of infested fruits at 3$^{rd}$ picking after 3$^{rd}$ spray was found in control (0.328 kg plot$^{-1}$). The lowest percent infestation by weight (5.66 %) was also found in Tracer 45 SC (Spinosad) followed by Lumectin 10 WDG (11.02 %) and the highest percent infestation by weight was found in the control (61.86%) treatment.

From the above findings, it was observed that the highest weight of healthy fruits was found in Tracer 45 SC (Spinosad) and the lowest was in the control treatment. The lowest weight of infested fruit was found in Tracer 45 SC (Spinosad) and highest in the control treatment. The percent fruit infestation was also lowest in Tracer 45 SC (Spinosad) and the highest in the control.

**Table 5:** Efficacy of selected biopesticides on weight of healthy fruits, weight of infested fruits and percent infestation by weight after 1st picking.

| Treatments | Weight (Kg) of healthy fruits | Weight (Kg) of infested fruits | % Infestation by weight |
|---|---|---|---|
| Ecomec 1.8 EC (Abamectin) | 0.282 ± 0.023 bc | 0.085 ± 0.006 b | 23.46 ± 2.68 bc |
| Sunmectin 1.8 EC (Abamectin) | 0.202 ± 0.017 cd | 0.084 ± 0.014 b | 29.17 ± 5.51 b |
| Lumectin 10 WDG (Emamectin benzoate and Lufenuron) | 0.214 ± 0.013 cd | 0.074 ± 0.005 b | 25.71 ± 1.68 b |
| Tracer 45 SC (Spinosad) | 0.426 ± 0.022 a | 0.053 ± 0.010 b | 11.12 ± 2.21 d |
| Green Meta *(Metarhizium anisopilae)* | 0.336 ± 0.058 ab | 0.054 ± 0.012 b | 13.82 ± 1.28 cd |
| Control | 0.152 ± 0.0299 d | 0.145 ± 0.008 a | 49.84 ± 5.62 a |
| LSD | 0.101 | 0.034 | 10.09 |
| CV | 21.01 | 22.55 | 21.72 |
| Level of significance | ** | ** | ** |

Mean values within column followed by different letters are significantly different at 5% level of probability by LSD. ± SE indicates standard error, DBS[1]: Days before spray, DAS[2]: Days after spray. ** indicates 1% level of significance

**Table 6:** Efficacy of selected biopesticides on weight of Healthy fruits, weight of Infested fruits and percent infestation by weight after 2nd picking.

| Treatments | Weight (Kg) of Healthy fruits | Weight (Kg) of Infested fruits | % Infestation by weight |
|---|---|---|---|
| Ecomec 1.8 EC (Abamectin) | 0.374 ± 0.05 bc | 0.073 ± 0.01 bc | 16.65 ± 3.43 bc |
| Sunmectin 1.8 EC (Abamectin) | 0.285 ± 0.02 c | 0.100 ± 0.02 bc | 25.40 ± 4.43 b |
| Lumectin 10 WDG (Emamectin benzoate and Lufenuron) | 0.402 ± 0.02 b | 0.076 ± 0.02 bc | 16.32 ± 3.58 bc |
| Tracer 45 SC (Spinosad) | 0.621 ± 0.02 a | 0.040 ± 0.00 c | 6.15 ± 0.18 c |
| Green Meta *(Metarhizium anisopilae)* | 0.394 ± 0.04 bc | 0.103 ± 0.02 b | 20.88 ± 4.04 b |
| Control | 0.150 ± 0.03 d | 0.243 ± 0.07 a | 62.06 ± 5.65 a |
| LSD | 0.110 | 0.061 | 12.73 |
| CV | 16.42 | 31.85 | 28.48 |
| Level of significance | ** | ** | ** |

Mean values within column followed by different letters are significantly different at 5% level of probability by LSD. ± SE indicates standard error, DBS[1]: Days before spray, DAS[2]: Days after spray. ** indicates 1% level of significance

**Table 7:** Efficacy of selected biopesticides on the weight of healthy fruits, weight of infested fruits and percent infestation by weight after 3rd picking.

| Treatments | Weight (Kg) of Healthy fruits | Weight (Kg) of Infested fruits | % Infestation by weight |
|---|---|---|---|
| Ecomec 1.8 EC (Abamectin) | 0.485 ± 0.05 b | 0.09 ± 0.01 bc | 16.30 ± 2.99 c |
| Sunmectin 1.8 EC (Abamectin) | 0.480 ± 0.03 b | 0.102 ± 0.01 bc | 17.59 ± 0.64 c |
| Lumectin 10 WDG (Emamectin benzoate and Lufenuron) | 0.468 ± 0.07 b | 0.058 ± 0.01 c | 11.02 ±1.04 cd |
| Tracer 45 SC (Spinosad) | 0.776 ± 0.05 a | 0.046 ± 0.00 c | 5.66 ± 2.15 d |
| Green Meta *(Metarhizium anisopilae)* | 0.401 ± 0.03 b | 0.147 ± 0.03 b | 26.41 ± 4.65 b |
| Control | 0.202 ± 0.02 c | 0.328 ± 0.03 a | 61.86 ± 1.78 a |
| LSD | 0.158 | 0.062 | 8.11 |
| CV | 18.62 | 26.85 | 19.28 |
| Level of significance | ** | ** | ** |

Mean values within column followed by different letters are significantly different at 5% level of probability by LSD. ± SE indicates standard error, DBS[1]: Days before spray, DAS[2]: Days after spray. ** indicates 1% level of significance

### 4.7 Efficacy of five biopesticides on the yield of bitter gourd

The efficacy of five selected bio-pesticides on marketable fruit yield increases over control in bitter gourd is shown in Table 8. The marketable fruit yield (kg plot$^{-1}$) after 1$^{st}$, 2$^{nd}$ and 3$^{rd}$ picking of bitter gourd were significantly different ($F$= 9.45,19.40, 13.42 $df$=5, $P$< 0.01) (Appendix Table 5) among the treatments. The highest yield (0.426 kg plot$^{-1}$) was found in Tracer 45 SC (Spinosad) followed by Green meta (*M. anisopliae* (0.336 kg plot$^{-1}$) but the lowest yield (0.152 kg plot$^{-1}$) was found in control at 1$^{st}$ picking after 1$^{st}$ spray. The highest yield (0.621 kg plot$^{-1}$) was found in Tracer 45 SC (Spinosad) followed by Lumectin 1.8 EC (0.402 kg plot$^{-1}$) but the lowest yield (0.150 kg plot$^{-1}$) was also found in control at 2$^{nd}$ picking. In 3$^{rd}$ picking the marketable fruit was highest in Tracer 45 SC (Spinosad) (0.776 kg plot$^{-1}$) followed by Ecomec 1.8 EC (Abamectin) (0.485 kg plot$^{-1}$) and the lowest marketable fruit was in control (0.202 kg plot$^{-1}$) as in 1$^{st}$ and 2$^{nd}$ picking. The cumulative yield of marketable bitter gourd fruits (kg plot$^{-1}$) was significantly different ($F$=12.76, $df$=5, $P$<0.01) (Appendix Table 5) among the treatments. The highest cumulative yield (1.832 kg plot$^{-1}$) was recorded in tracer 45 SC followed by Ecomec 1.8 EC (Abamectin) (1.143 kg plot$^{-1}$) but the lowest result was found in control (0.503 kg plot$^{-1}$). The yield of the treatments increased (times) differently over control. The highest yield of marketable fruits increased (3.62 times) was found in tracer 45 SC followed by (2.27 times) in Ecomec 1.8 EC (Abamectin). Other treatments viz. Green Meta (2.24 times), Lumectin 10 WDG (2.16 times), and Sunmectin 1.8 EC (1.92 times) also increased over control. From the above result, it is found that the cumulative weight of healthy or marketable fruits was highest in Tracer 45 SC (Spinosad) and the yield also increased highest (3.62 times) in Tracer 45 SC over control. A similar result was also reported by Rahman *et al*. (2019) where they found that the application of Spinosad against cucurbit fruit fly on bitter gourd provided the highest (1.5 times) increase in fruit yield over control. Rahman *et al.* (2019) showed that

Spinosad had a 1.56 times higher yield than the control and the result is lower than the present study.

**Table 8:** Weight of cumulative yield with increase (times) over control bitter gourd

| Treatments | Yield (kg plot$^{-1}$) of marketable fruits | | | Cumulative yield | % Increases Over control (Times) |
|---|---|---|---|---|---|
| | 1st Picking | 2nd picking | 3rd picking | | |
| Ecomec 1.8 EC (Abamectin) | 0.282 ± 0.023 bc | 0.374 ± 0.05 bc | 0.485 ± 0.05 b | 1.143 ± 0.09 b | 2.27 |
| Sunmectin 1.8 EC (Abamectin) | 0.202 ± 0.017 cd | 0.285 ± 0.02 c | 0.480 ± 0.03 b | 0.967 ± 0.03 b | 1.92 |
| Lumectin 10 WDG (Emamectin benzoate and Lufenuron) | 0.214 ± 0.013 cd | 0.402 ± 0.02 b | 0.468 ± 0.07 b | 1.087 ± 0.06 b | 2.16 |
| Tracer 45 SC (Spinosad) | 0.426 ± 0.022 a | 0.621 ± 0.02 a | 0.776 ± 0.05 a | 1.823 ± 0.10 a | 3.62 |
| Green Meta *(Metarhizium anisopilae)* | 0.336 ± 0.058 ab | 0.394 ± 0.04 bc | 0.401 ± 0.03 b | 1.13 ± 0.12 b | 2.24 |
| Control | 0.152 ± 0.0299 d | 0.150 ± 0.03 d | 0.202 ± 0.02 c | 0.503 ± 0.03 c | |
| LSD | 0.101 | 0.110 | 0.158 | 0.276 | |
| CV | 21.01 | 16.42 | 18.62 | 13.69 | |
| Level of significance | ** | ** | ** | ** | |

Mean values within column followed by different letters are significantly different at 5% level of probability by LSD. ± SE indicates standard error, DBS[1]: Days before spray, DAS[2]: Days after spray. ** indicates 1% level of significance

### 4.8 Mortality of *Coccinella septempunctata* adults exposed to different pesticide residues at 1, 3 and 7 days after treatment

In our study Abamectin (Sunmectin 1.8 EC) and Tracer 45 SC (Spinosad) residues caused (100%, 80%), (80%,36%) and (20%, 10%) mortality of *C. septempunctata* at 1 DAT, 3 DAT, 7 DAT respectively (Table 9). Legaspi *et al*. (2001) also claimed that a 7-day-old residue of Abamectin is safe for twice-stabbed lady beetle, *Chilocorus cacti* (L.). In the case of Ecomec 1.8 EC, Lumectin 10 WDG and *M. anisopliae* the residual effect was (46%, 40% and 20%) and (40%, 40% and 0.00%) at 1 DAT and 3 DAT after spray. At 7 DAT mortality percentage was 0.00 in Abamectin (Ecomec 1.8 EC), Emamectin benzoate and Lufenuron (Lumectin 10 WDG) and *Metarhizium anisopliae* (Green Meta).

**Table 9:** Mortality percentage of *C. septempunctata* adults exposed to different pesticides residues at 1, 3 and 7 days after treatment.

| Treatments | 1 DAT[3] | 3 DAT[3] | 7 DAT[3] |
|---|---|---|---|
| Ecomec 1.8 EC (Abamectin) | 46 ± 9.26 c | 40 ± 9.09 b | |
| Sunmectin 1.8 EC (Abamectin) | 100 ± 0.00 a | 80 ± 7.43 a | 20.00 ± 7.43 a |
| Lumectin 10 WDG (Emamectin benzoate and Lufenuron) | 40 ± 9.09 c | 40 ± 9.09 b | 0.00 ± 0.00 b |
| Tracer 45 SC (Spinosad) | 80 ± 7.42 b | 36 ± 8.94 b | 10.00 ± 5.57 ab |
| Green Meta *(Metarhizium anisopilae)* | 20 ± 7.43 d | 0.00 ± 0.00 c | 0.00 ± 0.00 b |
| Control | 00 ± 0.00 e | 0.00 ± 0.00 c | 0.00 ± 0.00 b |

Mean values within column followed by different letters are significantly different at 5% level of probability by LSD. ± SE indicates standard error, DAT[3]: Days after treatment.

**4.9 Efficacy of selected biopesticides on the number of maggots inside the infested fruits after 1st, 2nd and 3rd picking of infested fruits.**

Figure 2 shows that the number of maggots inside the infested fruits after 1st picking. The lowest number of maggots was found when treated with Tracer 45 SC (Spinosad) (2.33) followed by Sunmectin 1.8 EC (3.33) and Lumectin 10 WDG (3.5) but the other treatments were statistically identical. The highest number of maggots was found in the control (6.13) as compared to other treatments. (Top figure)

In the case of 2nd picking the lowest number of maggots was also found when treated with Tracer 45 SC (3.33) followed by Ecomec 1.8 EC (3.67) but the other treatments were statistically similar. The highest number of maggots was found in the control (5.95) as compared to the other treatments. (Middle figure)

Further, the Tracer 45 SC performed the best at the 3rd picking of infested fruits. It showed that Tracer 45 SC had the lowest (3.00) number of maggots inside the infested fruits. The Ecomec 1.8 EC and Green meta (*M. anisopliae)* was statistically identical to Sumnectin 1.8 EC and Lumectin 10 WDG. The highest number of maggots was found in the control (6.67). The result is similar to the findings of Srinivas *et al.* (2018) reported that the lowest mean number of fruit fly maggots (8.0 and 8.93/fruit) was found in bitter gourd when treated with Tracer 45 SC (Spinosad). (Bottom figure)

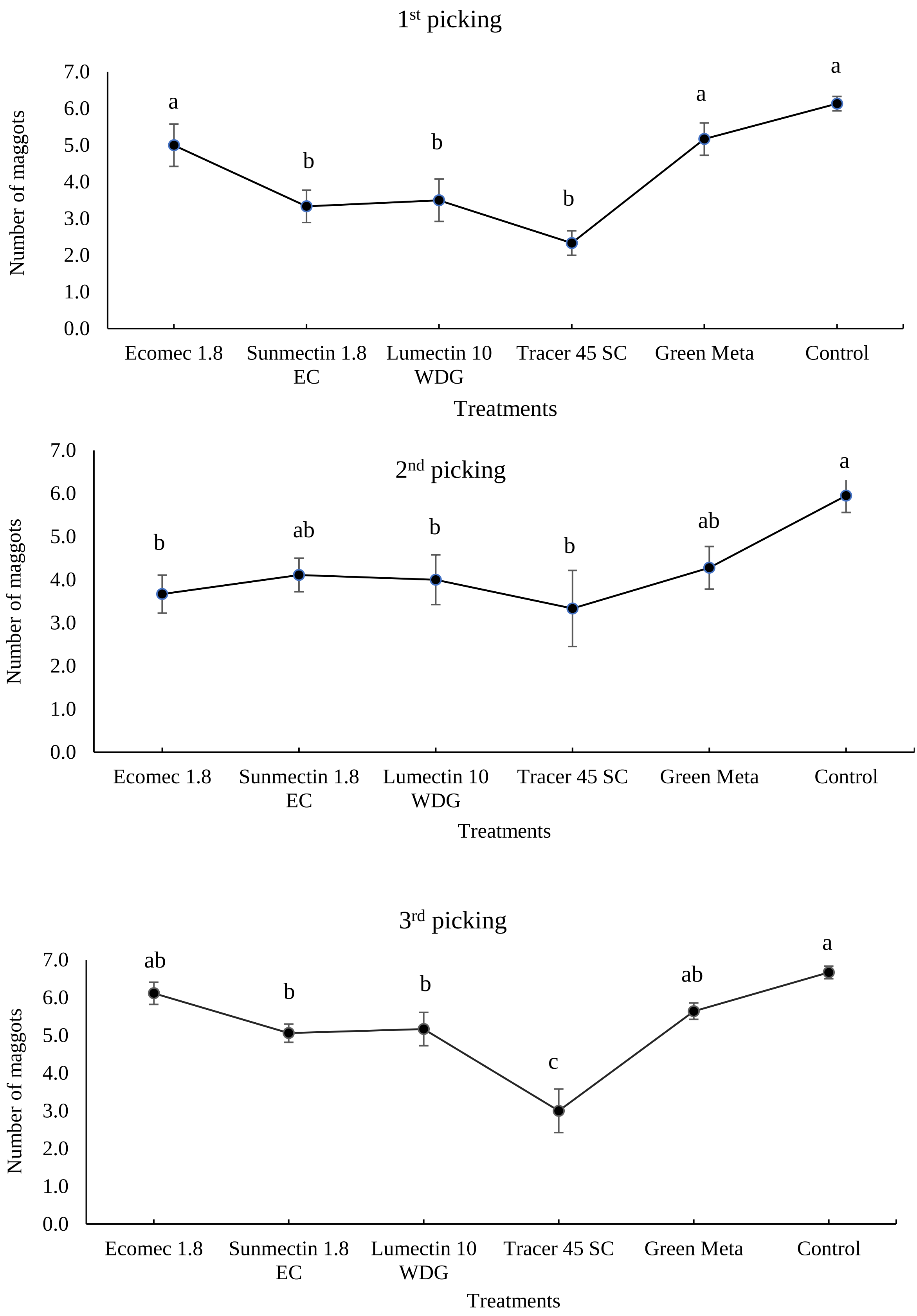



**Fig 2:** Number of maggots counted from infested fruits of different treatments at 1st, 2nd and 3rd picking

# CHAPTER V

## SUMMARY AND CONCLUSION

During February to June a field experiment was conducted at the field of Entomology Department, HSTU, Dinajpur to evaluate the efficacy of some selected biopesticide against cucurbit fruit fly, *B. cucurbitae* on bitter gourd.

Different biopesticides seems to be effective in the management of cucurbit fruit fly in bitter gourd. Total three spray were applied on bitter gourd plots of different replication during the experiment and three picking of healthy fruits and infested fruits were done at every 8 Days after spray. The number of healthy fruits and infested fruits was counted at 1 day before, 3 and 7 days after spray. The eight of healthy fruits, infested fruits, percent fruit infestation, cumulative weight and the weight increase over control were also calculated. The number of maggots inside infested fruits were also counted after every picking.

Result showed that the lowest percent of infestation was 16.20% after 1$^{st}$ spray and 10.44% in both 2$^{nd}$ and 3$^{rd}$ spray. The highest percent reduction of infestation over control was 68.75%, 84.39% and 85.33% found in the treatment of Tracer 45 SC (Spinosad) after 1$^{st}$, 2$^{nd}$ and 3$^{rd}$ spray. Spinosad also showed the highest weight of healthy fruits (0.0426 kg plot$^{-1}$, 0.621 kg plot$^{-1}$ and 0.776 kg plot$^{-1}$) and lowest percent of infestation by weight (11.12%, 6.15% and 5.66%) in all the 3 consecutive picking after 1$^{st}$ ,2$^{nd}$ and 3$^{rd}$ spray in Tracer 45 SC (Spinosad). The cumulative yield was highest (1.832 kg) in Tracer 45 SC (Spinosad) and it increase the yield 3.62 over control. The number of maggots inside the infested fruits also found the lowest in Tracer 45 SC (Spinosad) (2.33) and the highest in control (6.67) plot. The residual effect on *C. septempunctata* was 100% at 1 DAT in case of Sunmectin 1.8 EC (Abamectin) 80% in Tracer 45 SC (Spinosad), 46% in Ecomec 1.8 EC (Abamectin) ,40% in Lumectin 10 WDG (Emamectin benzoate and Lufenuron), 20% in *M. anisopliae* at 3DAT. Tracer 45 SC (Spinosad) showed only 10% in 7 DAT. According to the analysis we can summarize that after 1st, 2nd and 3rd spraying and picking of bitter gourd, Tracer 45 SC (Spinosad) showed comparatively effective result against fruit fly than the other treatments. In case of healthy and marketable and the cumulative weight of all the three picking the Tracer 45 SC (Spinosad) showed the highest 1.823 kg which increased 3.62 times over control plot. The number of maggots inside the infested fruits also found the lowest (2.33) in Tracer 45 SC (Spinosad). Based on the result we can suggest that fruits of bitter gourd can be treated with Tracer 45 SC (Spinosad) against cucurbit fruit fly (*B. cucurbitae)* to evaluate the lower number of infested fruit and percent fruit infestation and higher number of healthy fruits and higher yield of bitter gourd.

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## APPENDICES

**Appendix Table 1:** ANOVA tables for the number of percent fruit infestation (by number) at 1st spraying of treatment

| Different time interval | Source of variation (SV) | Drees of freedom (df) | Sum of Squares (SS) | Mean Square (MS) | F- value | P-Value | Coefficient of Variation (CV) (%) |
|---|---|---|---|---|---|---|---|
| DBS (% fruit infestation) | Replication | 2 | 548.23 | 274.11 | 0.22 | 0.9468 | 29.24 |
| | Factor A | 5 | 157.43 | 31.485 | | | |
| | Error | 10 | 1444.88 | 144.488 | | | |
| | Total | 17 | 2150.53 | | | | |
| 3 DAS (% fruit infestation) | Replication | 2 | 142.58 | 71.29 | 8.73 | 0.0020 | 20.16 |
| | Factor A | 5 | 2094.33 | 418.87 | | | |
| | Error | 10 | 479.74 | 47.97 | | | |
| | Total | 17 | 2716.65 | | | | |
| 7 DAS (%fruit infestation) | Replication | 2 | 283.60 | 141.802 | 27.17 | 0.00 | 17.42 |
| | Factor A | 5 | 4863.64 | 972.729 | | | |
| | Error | 10 | 358.07 | 35.807 | | | |
| | Total | 17 | 5505.32 | | | | |
| Cumulative mean of 3 & 7 DAS | Replication | 2 | 203.82 | 101.908 | 20.12 | 0.0001 | 16.45 |
| | Factor A | 5 | 3213.32 | 642.664 | | | |
| | Error | 10 | 319.47 | 31.947 | | | |
| | Total | 17 | 3736.60 | | | | |

**Appendix Table 2:** ANOVA tables for the number of percent fruit infestation (by number) at 2nd spraying of treatment

| Different time interval | Source of variation (SV) | Drees of freedom (df) | Sum of Squares (SS) | Mean Square (MS) | F- value | P-Value | Coefficient of Variation (CV) (%) |
|---|---|---|---|---|---|---|---|
| DBS (% fruit infestation) | Replication | 2 | 131.77 | 65.883 | 2.50 | 0.1023 | 30.30 |
| | Factor A | 5 | 1766.21 | 353.241 | | | |
| | Error | 10 | 1414.57 | 141.457 | | | |
| | Total | 17 | 3312.54 | | | | |
| 3 DAS (% fruit infestation) | Replication | 2 | 42.25 | 21.13 | 19.60 | 0.0001 | 22.59 |
| | Factor A | 5 | 5641.07 | 1125.21 | | | |
| | Error | 10 | 575.61 | 57.56 | | | |
| | Total | 17 | 6258.93 | | | | |
| 7 DAS (%fruit infestation) | Replication | 2 | 68.77 | 34.38 | 65.53 | 0.000 | 15.90 |
| | Factor A | 5 | 9106.98 | 1821.40 | | | |
| | Error | 10 | 277.95 | 27.80 | | | |
| | Total | 17 | 9453.70 | | | | |
| Cumulative mean of 3 & 7 DAS | Replication | 2 | 48.87 | 24.44 | 67.56 | 0.000 | 13.85 |
| | Factor A | 5 | 7219.94 | 1443.99 | | | |
| | Error | 10 | 213.74 | 21.37 | | | |
| | Total | 17 | 7482.55 | | | | |

**Appendix Table 3:** ANOVA tables for the number of percent fruit infestation (by number) at 3rd spraying of treatment

| Different time interval | Source of variation (SV) | Drees of freedom (df) | Sum of Squares (SS) | Mean Square (MS) | F- value | P-Value | Coefficient of Variation (CV) (%) |
|---|---|---|---|---|---|---|---|
| DBS (% fruit infestation) | Replication | 2 | 137.00 | 68.49 | | | |
| | Factor A | 5 | 2257.84 | 451.57 | 6.25 | 0.0070 | 21.55 |
| | Error | 10 | 722.30 | 72.23 | | | |
| | Total | 17 | 3117.13 | | | | |
| 3 DAS (% fruit infestation) | Replication | 2 | 61.41 | 30.71 | | | |
| | Factor A | 5 | 7133.81 | 1426.76 | 20.10 | 0.0001 | 25.03 |
| | Error | 10 | 709.99 | 71.00 | | | |
| | Total | 17 | 7905.21 | | | | |
| 7 DAS (%fruit infestation) | Replication | 2 | 3.93 | 1.96 | | | |
| | Factor A | 5 | 8284.89 | 1656.98 | 40.40 | 0.000 | 19.43 |
| | Error | 10 | 410.18 | 41.02 | | | |
| | Total | 17 | 8698.99 | | | | |
| Cumulative mean of 3 & 7 DAS | Replication | 2 | 18.09 | 9.05 | | | |
| | Factor A | 5 | 7668.98 | 1533.80 | 35.80 | 0.000 | 19.64 |
| | Error | 10 | 428.38 | 42.84 | | | |
| | Total | 17 | 8115.46 | | | | |

**Appendix Table 4:** ANOVA tables for the weight of healthy, infested and % infestation at 1st, 2nd and 3rd picking of treatment

| Different time interval | Source of variation (SV) | Drees of freedom (df) | Sum of Squares (SS) | Mean Square (MS) | F- value | P-Value | Coefficient of Variation (CV) (%) |
|---|---|---|---|---|---|---|---|
| 1st picking (Healthy) | Replication | 2 | 0.00316 | 0.00158 | | | |
| | Factor A | 5 | 0.15080 | 0.03016 | 9.45 | 0.0015 | 21.01 |
| | Error | 10 | 0.03191 | 0.00319 | | | |
| | Total | 17 | 0.18588 | | | | |
| 1st picking (Infested) | Replication | 2 | 0.00013 | 0.000065 | | | |
| | Factor A | 5 | 0.01716 | 0.003432 | 9.82 | 0.0013 | 22.55 |
| | Error | 10 | 0.00349 | 0.000349 | | | |
| | Total | 17 | 0.02078 | | | | |
| 1st picking % infestation | Replication | 2 | 18.80 | 9.40 | | | |
| | Factor A | 5 | 2864.00 | 572.80 | 18.64 | 0.0001 | 21.72 |
| | Error | 10 | 307.32 | 30.73 | | | |
| | Total | 17 | 3190.12 | | | | |
| 2nd picking (Healthy) | Replication | 2 | 0.00358 | 0.00179 | | | |
| | Factor A | 5 | 0.36050 | 0.07210 | 19.40 | 0.0001 | 16.42 |
| | Error | 10 | 0.03716 | 0.00372 | | | |
| | Total | 17 | 0.40124 | | | | |
| 2nd picking (Infested) | Replication | 2 | 0.00341 | 0.00170 | | | |
| | Factor A | 5 | 00.07352 | 0.01470 | 13.34 | 0.0004 | 31.59 |
| | Error | 10 | 0.01102 | 0.00110 | | | |
| | Total | 17 | 0.08795 | | | | |
| 2nd picking % infestation | Replication | 2 | 65.24 | 32.62 | | | |
| | Factor A | 5 | 5669.98 | 1134.00 | 23.15 | 0.000 | 28.48 |
| | Error | 10 | 489.82 | 48.98 | | | |
| | Total | 17 | 6225.04 | | | | |
| 3rd picking (Healthy) | Replication | 2 | 0.00889 | 0.00445 | | | |
| | Factor A | 5 | 0.51205 | 0.10241 | 13.42 | 0.0004 | 18.62 |
| | Error | 10 | 0.07628 | 0.00763 | | | |
| | Total | 17 | 0.59723 | | | | |
| 3rd picking (Infested) | Replication | 2 | 0.00252 | 0.00126 | | | |
| | Factor A | 5 | 0.16164 | 0.03233 | 27.01 | 0.000 | 26.85 |
| | Error | 10 | 0.01197 | 0.00120 | | | |
| | Total | 17 | 0.17613 | | | | |
| 3rd picking % infestation | Replication | 2 | 14 | 7.04 | | | |
| | Factor A | 5 | 6119.79 | 1223.96 | 61.52 | 0.00 | 19.28 |
| | Error | 10 | 198.95 | 19.89 | | | |
| | Total | 17 | 6332.82 | | | | |

**Appendix Table 5:** ANOVA table for the cumulative yield of marketable fruits at 1st, 2nd and 3rd picking after 1st, 2nd and 3rd spray

| Different time interval | Source of variation (SV) | Drees of freedom (df) | Sum of Squares (SS) | Mean Square (MS) | F- value | P-Value | Coefficient of Variation (CV) (%) |
|---|---|---|---|---|---|---|---|
| 1st picking (marketable) | Replication | 2 | 0.00316 | 0.00158 | 9.45 | 0.0015 | 21.01 |
| | Factor A | 5 | 0.15080 | 0.03016 | | | |
| | Error | 10 | 0.03191 | 0.00319 | | | |
| | Total | 17 | 0.18588 | | | | |
| 2nd picking (marketable) | Replication | 2 | 0.00358 | 0.00179 | 19.40 | 0.0001 | 16.42 |
| | Factor A | 5 | 0.36050 | 0.07210 | | | |
| | Error | 10 | 0.03716 | 0.00372 | | | |
| | Total | 17 | 0.40124 | | | | |
| 3rd picking (marketable) | Replication | 2 | 0.00889 | 0.00445 | 13.42 | 0.0004 | 18.62 |
| | Factor A | 5 | 0.51205 | 0.10241 | | | |
| | Error | 10 | 0.07628 | 0.00763 | | | |
| | Total | 17 | 0.59723 | | | | |
| Cumulative yield (marketable) | Replication | 2 | 0.00045 | 0.00023 | 12.76 | 0.000 | 32.08 |
| | Factor A | 5 | 0.89738 | 0.17948 | | | |
| | Error | 10 | 0.64698 | 0.01406 | | | |
| | Total | 17 | 1.54481 | | | | |

**Appendix Table 6:** ANOVA tables for the residual effect of 1, 3 and 7 DAT on *Coccinella septempunctata* (L.)

| Different time interval | Source of variation (SV) | Drees of freedom (df) | Sum of Squares (SS) | Mean Square (MS) | F- value | P-Value | Coefficient of Variation (CV) (%) |
|---|---|---|---|---|---|---|---|
| Residual effect at 1 DAT | Replication | 29 | 32444 | 1118.8 | 28.48 | 0.000 | 79.69 |
| | Factor A | 5 | 206444 | 42188.9 | | | |
| | Error | 145 | 210222 | 1449.8 | | | |
| | Total | 179 | 449111 | | | | |
| Residual effect at 3 DAT | Replication | 29 | 52444 | 1808.4 | 19.73 | 0.000 | 95.54 |
| | Factor A | 5 | 145778 | 29155.6 | | | |
| | Error | 145 | 214222 | 1477.4 | | | |
| | Total | 179 | 412444 | | | | |
| Residual effect at 7 DAT | Replication | 29 | 13833.3 | 477.01 | 4.98 | 0.0003 | 410 |
| | Factor A | 5 | 10500.0 | 2100.00 | | | |
| | Error | 145 | 61166.7 | 421.84 | | | |
| | Total | 179 | 85500.0 | | | | |