BIOLOGY AND MANAGEMENT OF CUCUMBER FRUIT FLY, *Bactrocera cucurbitae* (Coquillett)

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B.Sc. (Agriculture)

MASTER OF SCIENCE

IN

AGRICULTURE

(AGRICULTURAL ENTOMOLOGY)

DEPARTMENT OF AGRICULTURAL ENTOMOLOGY,

COLLEGE OF AGRICULTURE, PARBHANI

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PARBHANI - 431 402 (M.S.) INDIA

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By

PAWAR SWAPNIL SAMBHAJI

B.Sc. (Agriculture)

A thesis submitted to

Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani

in partial fulfilment of the requirements for the Degree of

MASTER OF SCIENCE

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2021

DECLARATION BY THE CANDIDATE

I hereby declare that the thesis entitled, **"BIOLOGY AND MANAGEMENT OF CUCUMBER FRUIT FLY, *Bactrocera cucurbitae* (Coquillett)"** submitted by me is based on the actual work carried out by me under the guidance and supervision of **Dhirajkumar Rajaram Kadam** the extent of information derived from the existing literature have been duly cited and referenced. The existing research work or its any part is not submitted anywhere else for the award of any degree or diploma.

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(Pawar Swapnil Sambhaji)

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ABBREVIATIONS

/	-	Per
_	-	Minus
+		Plus
%	-	Per cent
@	-	At the rate of
Agril.		Agriculture
Avg.	-	Average
Cm	-	Centimeter (s)
Conc.	-	Concentration (s)
C.D.	-	Critical difference
°C	-	Degree Celsius
Dia.	-	Diameter
e.g.,	-	Example Gratia (for example)
et al.,	-	and others
etc.	-	Etcetera
Fig.	-	Figure (s)
Gm	-	Gram
Ha	-	Hectare (s)
Hr	-	Hour (s)
i.e.	-	That is
Kg	-	Kilogram (s)
kg/ha	-	Kilograms per hectare
M	-	Meter (s)
Max.	-	Maximum
Min.	-	Minimum
Ml	-	Millilitre
Mm	-	Millimeter
no.	-	Number (s)
RBD	-	Randomized Block Design
Rs/ha	-	Rupees per hectare
S.E.	-	Standard Error

spp.	-	Species
Tr. and T	-	Treatment (s)
viz.,	-	Videlicet (namely)
w/v	-	Weight/Volume
±	-	Plus Minus
&	-	And
CC	-	Cubic centimeter
DAS	-	Days after sowing
DOG	-	Date of Germination
DOS	-	Date of sowing
EC	-	Emulsifiable concentrate
DBS	-	Day before spraying
L	-	Liter (s)
J	-	Journal
NS	-	Non significant
R.H.	-	Relative Humidity
SE (m) ±	-	Standard error of mean
Sig.	-	Significant
Sr.	-	Serial
Var	-	Variety
VNMKV	-	Vasantrao Naik Marathwada Krishi Vidhyapeeth

THESIS ABSTRACT

THESIS ABSTRACT

1.	Title of the Thesis	:	**"BIOLOGY AND MANAGEMENT OF CUCUMBER FRUIT FLY, *Bactrocera cucurbitae* (Coquillett)"**
2.	Name of student	:	Pawar Swapnil Sambhaji
3.	Name of Research Guide	:	Dr. D. R. Kadam
4.	Department	:	Agricultural Entomology
5.	University	:	VNMKV, Parbhani
6.	Degree to be awarded	:	M.Sc. (Agriculture)

ABSTRACT

The experiment "Biology and management of cucumber fruit fly, *Bactrocera cucurbitae* (Coquillett)" was conducted at VNMKV, Parbhani, during *Summer* 2020-2021, in randomized block design with eight treatments and three replications using *var.* gypsy. The study revealed that mean incubation period of eggs was 17.9 ± 3.62 hr. The average length and breadth of eggs were 1.12 mm ± 0.09 mm and 0.22 mm ± 0.04 mm. The apodous maggots develop through three instars. The average duration of first, second and third instar maggot was 0.75 ± 0.15, 1.89 ± 0.32 and 2.43 ± 0.33 days, respectively. The total maggot period was 5.07 ± 0.42 days. The first and second instar maggot measured on an average 1.60 ± 0.24 and 6.41 ± 0.81 mm in length and 0.27 ± 0.05 and 1.18 ± 0.09 mm in breadth. Average length and breadth of fullgrown maggot was 9.43 ± 0.79 and 2.06 ± 0.32 mm. The prepupal period ranged between 0.5- 1 day with its mean 0.77 ± 0.14 days. Whereas, pupal period ranged between 8-9 days with mean of 8.35 ± 0.45 days. Average length and breadth of prepupa was 6.42 ± 0.15mm and 1.98 ± 0.05 mm. The average length and breadth of pupa were 5.65 mm ± 0.14 mm and 2.43 mm ± 0.11 mm. The copulation lasted for a minimum of 2 hours to maximum of 4 hours with mean of 3.3 ± 0.78. The pre-oviposition, oviposition and post-oviposition period ranged between 10 to 15 days, 2 to 4 days and 1 to 3 days with average of 12.3 ± 1.55, 2.65 ± 0.72 and 2.05 ± 0.66 days respectively. The period from egg to death of adult male ranged between 27-43 days with mean of 34.6 ± 4.29 days, whereas female ranged between 30-46 days with

average of 38.35 ± 4.77 days. The number of eggs laid by female ranged from 53-87 with mean of 71.9 ± 11.41. Hatching percentage ranged between 81-86 with mean of 83.3 ± 1.68. Sex Ratio (Male:Female) ranged between 0.90 to 1.20 with average of 1.07 ± 0.09. The average length and breadth (with expanded wings) of male was 8.54 mm ± 0.13 mm and 11.43 mm ± 0.95 mm, with range of 8.0 mm to 8.69 mm and 9.95 mm to 12.64 mm respectively. whereas, the female measured on an average 9.8 mm ± 0.15 mm in length and 15.82 mm ± 0.63 mm in breadth (with expanded wings) with range of 9.45 - 9.97 mm and 14.83 - 16.68 mm respectively. When adult male and female fed on water only mean longevity observed was 22.8 ± 5.58 and 22.2 ± 4.81 with range of 12-32 days and 14-30 days respectively. When fed on water and honey (1:1) mean longevity observed was 2.7 ± 0.40 with range of 2-3 in male and 3.4 ± 0.44 with range of 3-4 in female. When no food or water was given longevity observed in male was 1.45 ± 0.42 with range of 1-2 and in female 1.4 ± 0.44 with range of 1-2 in male and female. Bio-efficacy of different treatments against cucumber fruit fly after two sprays revealed that the treatment spinosad was the best treatment which recorded minimum (13.93%) mean fruit infestation and was at par with emamectin benzoate (15.43%). Spinosad 45 recorded the highest yield of fruit (17.20ton/ha) and the highest benefit cost ratio was noticed in lambda cyhalothrin (1:50.90).

(**Keywords:**- Cucumber, biology, management, egg, larva, pupa, adult)

CHAPTER – I

INTRODUCTION

CHAPTER-I

INTRODUCTION

India is a major producer of vegetables and fruits and ranks first in production of fruits and second in the production of vegetables next to China. Vegetables and fruits constitute important source of nutritions for its enormous population. With increasing globalization, it has become a challenge to feed its own population and to export to various developed countries. This requires strict quality control and restrictive quarantine measures (Kapoor, 2005). Being large group of vegetables, cucurbits provide better scope to enhance overall productivity and production (Rai *et al*., 2008). Vegetables play important role in human diet as well as in economy of farmers. As they are rich sources of vitamins (vit-A, vit-B and vit-E), minerals, proteins, fibers, *etc*. which is most important part of the balanced diet. They are a good source of dietary fiber and low in fat, salt and sugar. It is suggested that an average man with vegetarian or non-vegetarian food habits needs to consume 50 g leafy vegetables, 150 g other vegetables and 100 g roots and tubers (Narsinga Rao, 2013). Eating more vegetables as part of an overall healthy diet is likely to reduce the risk of some chronic diseases.

Cucumber origin is difficult as no wild strains have been found. It is believed that Botanist Alphonse de Candolle (1806-1893), cucumbers originated in India roughly 3000 years ago, specifically in the Himalayas throughout the Northern Bay of Bengal. However other claim that cucumbers are native to present day Kuwait and Iraq.

Cucumber (*Cucumis sativus* L.) belongs to cucurbitaceae family which is used as vegetable crop while its fruits are used for pickle or salad purpose in India (Szalay, 2017). There are three main varieties of cucumber slicing, pickling and burpless or seedless. Cucumber is a creeping vine that grows up with supporting frames, wrapping around with thin spiraling tendrils. The plant may also root in a soilless medium, where by it will sprawl along the ground instead of a supporting structure. The vine has large leaves that form a canopy over the fruits. Cucumber is commonly used for food, medicinal and industrial purposes.

It is mild tasting, refreshing food and is easy to add to various dishes. Like other fruits and vegetables it is good source of nutrients. It contains several important vitamins [vitamin K (62%) and vitamin C (14%)] and minerals [Mg (10%), K (13%) Mn (12%) and soluble fiber which may help prevent constipation and increase regularity. Cucumber fruits consist of 95% water. Cucumber has various benefits such as provides hydration, bone health, cardiovascular health and play role in the control of diabetes (Anonymous, 2017).

Cucumber is essentially warm season crop but it is successfully grown in tropical, subtropical and temperate region. The optimum temperature requirement is 26.4℃. In India, due to wide- range of climatic conditions different types of vegetable and fruit crops are grown. In 2019-2020 the annual production of cucumber in India was 1638 million tones with 111 ha area under cultivation (Anonymous, 2020.). Haryana ranks first in cucumber production in India with 274 million tonnes and Maharashtra ranks 9th with production of 58.95 million tonnes (Anonymous, 2018).

Cucurbitaceous crops are attacked by a number of insect pests and mites but in India only fruit flies and few species of beetles are of economic importance; aphids and blister beetles occurs regularly and cause severe damage, rest of the insect pests and mites are of minor importance (Butani and Jotwani, 1984). The family Tephritidae (True Fruit Flies) is one of the largest, most diversified and fascinating families of Diptera which includes more than 4200 known species arranged in 471 genera (Norrbom *et al*., 1998). The melon fruit fly, *Bactrocera cucurbitae* (Coquillett) (Diptera: Tephritidae) is widely distributed throughout the temperate, tropical and subtropical regions of the world. It is the only Tephritidae species in India that is uniformly widespread, attacking a large array of cucurbit fruits. It has more than 81 host species, in which fruit losses can range from 30 to 100% (Dhillon *et al*., 2005). The extent of losses varies between 30 to 100%, depending on the cucurbit species and the season (Sapkota *et al*., 2010, Nath and Bhusan 2006).

The melon fruit fly is considered a federal quarantine pest due to its highly harmful nature and cause extensive damage to many fruits and vegetables. The maggots of *Bactrocera cucurbitae* are responsible for causing damage by feeding internally on fruit pulp and make tunnels in fruits. The infested fruits become rotten and shed up prematurely. Sometimes, female adults make pseudo-puncture on the

skin of the young fruits which also reduce market price adversely (Khatun *et al*., 2015 and Dhillon *et al*., 2005). In addition to direct losses, fruit fly infestation can result in serious losses in trade value and export opportunity due to strict quarantine regulations imposed by most importing countries. (Chen and Ye 2007).

Cucumber fruit fly, *B. cucurbitae* is one of the most destructive pests of cucurbit vegetables that cause direct yield loss and also affects the quality of fruits. In cucumber this fruit fly was reported to cause up to 100 per cent damage (Atwal and Dhaliwal, 2005). It is serious pest of cucumber, bitter gourd, squash gourd, sponge gourd *etc*. Yield losses of 90 % to 100 % can occur due to this pest (Sapkota *et al*., 2010). In India, because of the polyphagous nature of the pest (maggot), fruit flies are considered as one of the ten most serious insect pests of the entire Agriculture. Nine species out of 207 species of fruit flies found to be the major and economically important in India. For the complete success or for developing any other strategy for fruit fly suppression, the knowledge of biology with different life stages of fruit fly is important (Mir *et al*., 2014).

As all the cultivated cucurbits are vines or creepers, they provide enough hiding places to the insect pests. Even then, many research workers had strongly recommended the chemical control measures as the most effective and economical tool than any other method of insect control. Several management techniques are being applied against cucumber fruit fly. More ever repeated use of toxic insecticides is not only hazardous to the environment but also directly affect the health of the farmers and consumers. Therefore it is necessary to explore economically sustainable and environment friendly newer insecticides for management of fruit fly. (Srinivas *et al*., 2018).

Hence, keeping the above points in view, the present investigation was under taken on "Biology and Management of cucumber Fruit fly, *Bactrocera cucurbitae* (Coquillett)" with following objectives.

1. To study the biology of cucumber fruit fly, *Bactrocera cucurbitae*
2. To study the bio-efficacy of newer insecticides against cucumber fruit fly, *Bactrocera cucurbitae*

CHAPTER – II

REVIEW OF LITERATURE

CHAPTER-II

REVIEW OF LITERATURE

The present investigation was carried out to study biology and bio-efficacy of newer insecticide against cucumber fruit fly *Bactrocera cucurbitae* (Conquillett). In the context of earlier studies and the published literature pertaining to above topics are reviewed and presented below under following heads.

2.1 Biology of cucumber fruit fly, *Bactrocera cucurbitae*

2.2 Bio-efficacy of newer insecticides against cucumber fruit fly, *Bactrocera cucurbitae*

2.1 Biology of cucumber fruit fly, *B. cucurbitae*

Lal and Sinha (1959) documented that while studying the biology of melon fly, *B. cucurbitae* eggs were white in colour, slightly curved, elongated, tapering at one end while rounded at the other end, the average length and breadth of eggs were 1.00 and 0.24 mm. Freshly hatched maggot was transparent and elongated full grown maggot to be creamy white in colour, pointed body at one end and broader at the other end with distinct body segments, while the average length and breadth was 10.62 and 2.11mm. The pupae to be barrel shaped, brownish grey in colour with pronounced body segments, had average length and breadth as 6.24 mm and 2.55 mm. Mating among the adult flies was observed at dusk where males were more active than the females.

Narayanan and Batra (1960) revealed that the freshly laid eggs of fruit fly were cylindrical slightly curved, elongated, shiny white in colour and tapering towards either end, the posterior end being broadly rounded, while the anterior end was more pointed. The length of egg ranged from 0.75 to 1.26 mm with a mean of 1.03 ± 0.16 mm and breadth ranged from 0.16 to 0.30 mm with a mean of 0.23 ± 0.04 mm. The full- grown maggot had the peculiar habit of curving and springing into the air to a distance by sudden relaxation of certain muscles. The full -grown maggot measured 9 to10 mm and 2 mm in length and breadth, across 10 the thorax. The duration of pre-pupal period varies from less than six to as long as 24 hours. The pupa

to be barrel shaped, light brown or pale coloured which turned ochraceous as it developed, had eleven segments and measured 5.5 mm long and 2 mm broad.

Doharey (1983) revealed that the egg incubation period on pumpkin, bitter gourd and squash gourd has been reported to be 4.0 to 4.2 days at temperature of 27 ± 1 ºC. The maggot period was 3 to 8 days the pupal period of fruit fly last for 7 days on bitter gourd and 7.2 days on pumpkin and squash gourd at 27±1 ºC temperature.

Shivarkar and Dumbre (1985) reported that the total maggot period was of 6.15 days mean pre-oviposition and oviposition periods were 9.53 and 2.33 days. The number of eggs laid on a single day varied from five to twenty-eight, whereas, the sex ratio of male and female as 1: 0.96 male longevity as 7.7 days while female lived for 17.13 days.

Agarwal *et al.,* (1987) reported that *B. cucurbitae* pupa was barrel shaped, light brown or pale coloured and measured 5-8 mm long and 2.00 mm broad, the pupal period was of 5-9 days.

Fletcher (1989) reported that the females deposit their eggs into ripening host fruit. Apodous maggots pass through three instars before puparium formation. The freshly laid eggs were cylindrical slightly curved, elongated, shiny white in colour and tapering towards either end, the posterior end being broadly rounded, while the anterior end was more pointed. The length of egg ranged from 0.75 to 1.26 mm with a mean of 1.03 ± 0.16 mm and breadth ranged from 0.16 to 0.30 mm with a mean of 0.23 ± 0.04 mm.

Koul and Bhagat (1994) revealed that the egg incubation period on bitter gourd has been reported to be 1.0 to 5.1 days. On different cucurbit species, the maggot period varied from 3 to 6 days. The pre-oviposition and oviposition periods ranged between 10.0- 16.3 and 5-15 days.

Gupta and Verma (1995) reported that on different cucurbit species, the maggot period varied from 3 to 6 days the pupal period varied from 7.7 to 9.4 days on bitter gourd, cucumber and sponge gourd, and 6.5 to 21.8 days on bottle gourd.

Hollingsworth *et al.,* (1997) reported that the development from egg to adult stage took 13 days at 29 ºC temperature in Solomon Islands. The egg incubation

period on bitter gourd has been reported to be 1.0 to 5.1 days. The maggot period lasted for 3 to 21 days depending on temperature and the host, the pupal period may vary from 7 to 13 days depending on temperature and the host.

Weems and Heppner (2001) studied the biology of fruit fly and reported that the egg was pure white in colour, about 2 mm long, elliptical, nearly flat on the ventral surface, more convex on the dorsal side and often somewhat curved puparium length as 5 to 6 mm and opined that colour varied from dull red or brownish yellow to dull white, depending upon the host. They reported about 8 to 10 generations in a year.

Kumar and Agarwal (2004) revealed that the eggs of *B. cucurbitae* were slightly curved on one side, whereas other side was straight and elongated; posterior end rounded while interior end was pointed. Egg length varied between 1.20 to 1.38 mm while width was 0.25 to 0.30 mm. Freshly hatched maggots of *B. cucurbitae* were transparent and elongated, creamy white in colour and measured 2.00 - 2.75 mm in length. The second instar maggot was creamy-whitish with more opaque body and measured 4.00 to 7.5 mm in length and were characterized by the presence of anterior spiracles. Third instar maggot ranged from 8.5 - 11.5mm in length and were whitish or yellowish-white in colour, whereas, puparia was usually pale-yellow coloured and measured 4.8 - 6.0 mm in length.

Shivayya *et al.*, (2007) found that freshly laid eggs were glittering, white, cylindrical, slightly curved and measured 1.57 mm in length and 0.34 mm in width. The duration of first instar was 28.09 ± 0.34 h and measured 2.18 mm long and 0.35 mm wide. The duration of second instar maggot to be 24 h and body measurements as 6.15 mm in length and 1.75 mm breadth, the maggot period was 7.50, 4.50 and 5.50 days during the month of December - January, March - April and August September respectively. The puparium was cylindrical or elliptical shaped, 4 to 6 mm long and 1.7 to 2.5 mm. The pupal period was 11.5, 7.0 and 10.7 days during December - January, March - April and August - September. The average pupal period was 7.3 ± 0.23, 10.3 ± 0.24 days during 2002 and 2003, respectively. The copulation lasted for a minimum of 2 to maximum of 6.5 h.

Mukherjee *et al.,* (2007) studied on the life history of *Bactrocera cucurbitae* (Diptera: Tephritidae) on sweet gourd and reported that the mean pre-oviposition,

oviposition, incubation, larval and pupal period were 11.25, 9.75, 0.81, 12.25 and 7.75 days, respectively. The mean longevity of adult male was 18.25 days and of adult female was 23.50 days. The mean fecundity of a female was 52.75. The average length of eggs, larvae, pupae, adult male and female were 1.48, 10.13, 6.00, 7.50 and 8.75 mm, respectively. Whereas, the mean breadth of eggs, larvae, pupae, adult male and female were 0.48, 3.38, 2.18, 3.25 and 5.50 mm, respectively.

Manzar and Srivastava (2009) reported that the freshly laid eggs were shiny, translucent and whitish in colour, cylindrical in shape but slightly curved and narrow at one end. The mean incubation period, temperature and relative humidity varied from 1.7 ± 0.12 days, 31.9 - 32.2 ºC and 56.7 - 62.8 per cent in 2002 and 1.4 ± 0.16 days, 27.3 - 30.8 ºC and 60.6 - 81.2 per cent in 2003. The duration of first instar was 28.09 ± 0.34 h and measured 2.18 mm long and 0.35 mm wide. Total maggot period as 5.9 ± 0.97 and 5.19 ± 0.24 days. The freshly formed pupa as cream coloured which turned dark yellow within 4 - 5 hours and later changed from brownish to ochroceous. The average pupal period was 7.3 ± 0.23, 10.3 ± 0.24 days during 2002 and 2003.

Barma and Jha (2011) studied on biology and reported that the incubation, larval, pupal and adult longevity periods were 2 to 5 days, 5 to 7 days, 6 to 9 days, 37 to 41 days in June-July and 4 to 6 days, 16 to 19 days, 17 to 21 days, 23 to 32 days in August-October, respectively.

Amin *et al.,* (2011) conducted a field experiment with a view to understand the fruit infestation rate by fruit fly, *B. cucurbitae* on ash gourd, ridge gourd, sweet gourd, bitter gourd and snake gourd, and life history of the fly on these cucurbitaceous crops. The highest (71.5%) and lowest (21.0%) fruit infestation rate was observed on sweet gourd and ridge gourd and the results were statistically different. Incubation periods varied from 18.3 to 25.0 hours and the shortest period was found on sweet gourd. Pre-oviposition, oviposition, larval and pupal periods, and adult male and female longevity varied from 10.8 to 15.7, 5.5 to 9.5, 11.3 to 15.3, 7.3 to 10.5, 11.3 to 17.3 and 15.0 to 20.8 days, respectively.

Waseem *et al*., (2012) examined the biology and life stages of of *B. cucurbitae*. He revealed that the egg length was 1.03 ± 0.16 mm while breadth 0.23 ± 0.04 mm the incubation period was 30.86 ± 0.12, 5.18± 0.67 and 9.29 ± 0.59 mm in length and 0.24 ± 0.04, 0.86 ± 1.00 and 1.76 ± 018 mm in breadth with duration of

0.60 ± 0.33 and 2.39 ± 0.32 days. The total maggot period ranged from 3 to 7 days. The prepupal period lasted for 12 to 24 hours, while the pupal period ranged from 5 to 9 days. Mating period ranged from 2 to 6 hours, pre – ovipositional period lasted for 15.76 ± 2.06 days while ovipositional period for 30.88 ± 8.93 days. Fecundity ranged from 90 to 205 eggs. Adults longevity ranged from 12 to 50 and 27 to 60 days in male and female.

Laskar (2013) studied on the biology and biometrics of melon fruit fly *B. cucurbitae* on bitter gourd and pumpkin under lab conditions. Findings of the study revealed that average length and breadth of egg was more or less similar when reared on bitter gourd and pumpkin (1.28 ± 0.059mm, 0.26 ± 0.057mm and 1.26 ± 0.060mm, 0.25 ± 0.053mm). Length and breadth of pre-pupal stage was noted slightly higher on bitter gourd (6.89±0.46mm and 2.04 ± 0.23mm) that pumpkin (6.70 ± 0.60mm and 1.99 ± 0.22mm). In both bitter gourd and pumpkin, size of females was larger than males. Fecundity and hatchability were noted very close on bitter gourd (138.40 ± 44.05 and 86.40 ± 7.09%) and pumpkin (135.60 ± 33.04 and 89.60 ± 6.07%). Sex ratio (male: female) was recorded 1.102 ± 0.136and 0.976 ± 0.104 on bitter gourd and pumpkins.

Langar *et al.,* (2013) reported that the female of *B. cucurbitae* laid 74.14 ± 0.68 eggs (clusters of 5-10) with a range of 50-91 eggs. *B. cucurbitae* females were highly prolific and laid eggs singly or in clusters of 5 to 10 with intervals of 2 - 5 days, sometimes even longer. A single female laid on an average 74.14 ± 4.90 eggs with the range of 50-91 eggs during its entire life span. The longevity periods recorded were 37.86 ± 1.40 and 40.84 ± 0.86 days for male and female.

Mir *et al.,* (2014) studied on biology of melon fruit fly, *B. cucurbitae* (Coquillett) and revealed that mean length and breadth of the eggs was found to be 1.13 ± 0.14 mm and 0.28 ± 0.05 mm. The first and second instars measured 1.49 ± 0.28 mm and 6.40 ± 0.86 mm in length, and 0.31 ± 0.07 mm and 1.21 ± 0.09 mm in breadth. The third instar measured 9.62 ± 0.87 mm in length and 2.05 ± 0.32 mm in breadth. The puparium measured 5.72 ± 0.13 mm in length and 2.46 ± 0.11 mm, whereas, the female measured 9.94 ± 0.20 mm in length and 15.92 ± 0.74 mm in breadth. The duration of egg incubation and the larval, prepupal and pupal periods were 16.8 ± 4.9 hours, and 4.5 ± 1.13, 0.8 ± 0.25 and 8.4± 0.51 days, respectively.

Pre-oviposition and oviposition periods ranged from 10-15 and 12-28 days. Fecundity varied from 58-92 eggs, while egg viability was 86.1 ± 0.54. Sex ratio (male: female) was 1.10 ± 0.14.

Rahaman *et al.,* (2015) studied the biology of fruit fly on bitter gourd and revealed that on an average, freshly laid eggs measured 0.78 mm in length and 0.16 mm in width; the average length of larva was 8.8 mm and width was 1.52 mm; the average length of pupa was 4.22 mm and width was 1.76 mm; the average length of the adult male was 13.78 mm and width was 7.06 mm, where the average length of the adult female was 15.62 mm and width was 8.86 mm. The mean incubation period was 6.98 days. The average larval developmental period was 18.66 days. The average pupal period was 21.3 days. The mean duration of adult stage was 27.67 days and the mean duration of egg to adult was 40.34 days.

Sharma *et al*., (2017) studied the biology and life cycle of cucumber fruit fly, in Jammu region and reveled that gravid female flies lay eggs in small clusters about 2 – 3 mm deep in fruit pulp. The average time period for completion of the life cycle by passing through various life stages *viz.* egg, larva, pupa and adult was 23.5±5.94. The longevity of adult male and female flies was about 1.3 ± 2.41 and 15.5 ± 3.49. Adults were strong fliers and had characteristic markings on the thorax and abdomen.

Das *et al.,* (2017) studied the biology of *B. cucurbitae* (Coq.) on pumpkin fruit. The average length and breadth of egg was 1.30 ± 0.08 and 0.25 ± 0.05 mm. The incubation period was 1.9 ± 0.65 day. The average length and breadth of first, second, and third instar maggots were 1.57 ± 0.26 and 0.25 ± 0.907, 4.71 ± 0.34 and 0.93 ± 0.31, 8.44 ± 0.88 and 1.57 ± 0.29 mm respectively. The average length and breadth of pupa was 5.65 ± 0.42 and 2.3 ± 0.18 mm. The pupal period was 6.2 ± 0.45 days. The average length and breadth of male and female were 6.79 ± 0.40 and 13.14 ± 1.05, 8.55 ± 0.71 and 14.95 ± 1.48 mm respectively. The male flies lived shorter (25 ± 8.72) than female (30 ± 10.07) days. Similarly, total life period of male was shorter (39.5 ± 8.82) than female (44.5 ± 10.56) days.

Sohrab *et al*., (2018) studied on the biology and life cycle of cucumber fruit fly, *B. cucurbitae* and reaveled mean pre-oviposition period of 13.5± 1.5 and oviposition period of 18.0 ± 6 days while, mean mating period (3 ± 1) hrs, fecundity 80.0 ± 20eggs/lifecycle and incubation period of eggs varied from 1.2 ± 0.25 days

was observed of cucurbit fruit fly. Hatching % of eggs of fruit fly 87.5 ± 2.5 was observed. The total maggot periods (three larval instars) was 5.180 ± 1.16 days while prepupal period and pupal period was 0.75 ± 0.25 and 9.5 ± 0.5 days. The average longevity of adult fruit flies were nither food nor water immediately, die after range of 1.5 ± 0.5 days after emergence from pupa. The duration of total life cycle was 16.81 ± 2.18 days.

Patel and Patel, (2018) studied the comparative biology of fruit fly, *B. cucurbitae* in different cucurbitaceous crops *viz*. bitter gourd, bottle gourd and watermelon in laboratory conditions. The mean incubation period, total larval period, pre pupal period, pupal period, adult male longevity, adult female longevity, fecundity, hatching percentage, sex ratio and total life cycle for male and female were recorded as 1.28 ± 0.458, 6.08 ± 0.493, 1.08 ± 0.277, 5.88 ± 0.600, 10.33 ± 0.617, 15.10 ± 0.738, 32 to 35 eggs, 92.00%, 1: 0.67, 24.80 ± 1.320, 29.20 ± 1.033 days respectively, for bitter gourd, 1.32 ± 0.476, 8.12± 0.332, 1.12 ± 0.332, 7.16 ± 0.374, 12.81 ± 0.655, 17.22 ± 0.833, 42 to 46 eggs, 88.00 %, 1: 0.56, 30.19 ± 0.750, 35.80 ± 1.814 days respectively, for bottle gourd 1.36 ± 0.700, 8.08 ± 0.812, 1.08 ± 0.277, 9.40 ± 0.645, 13.11 ± 2.111, 16.86 ± 2.734, 50 to 55 eggs, 80.00 %, 1: 0.39, 32.56 ± 2.382, 38.00 ± 3.512 days respectively, when the larva reared on watermelon.

Gaddanakeri and Rolania, (2020) studied biology and morphometrics of melon fruit fly (*B. cucurbitae* Coquillett) on bitter gourd. The mean incubation period of eggs was 18.0 ± 6.32 hours. The total maggot period ranged from 5 to 7 days with a mean period of 5.8 ± 0.78 days. Pupation took place inside the soil (5 to 6 cm thick) provided in cylindrical glass jar. Mean pupal duration was 6.9±0.87 days having a length and breadth of 5.98 ± 0.38 mm and 2.54 ± 0.14 mm. Total life period of male fruit fly ranged from 30 to 46 days with a mean of 36.2 ± 5.77 days. In case of female fruit fly total life period was slightly longer ranging from 32 to 50 days with a mean of 40.4±6.24 days. Sex ratio was recorded as 1: 0.84 (male:female).

Pradhan *et al.,* (2020) studied on biology and biometrics of melon fly by rearing the insect on seven different cucurbitaceous crops (hosts) *viz*., ash gourd, bitter gourd, bottle gourd, cucumber, pumpkin, ridge gourd and snake gourd. The order of preference of hosts based on incubation period (hours) were: ash gourd (19.35) < bitter gourd (19.56) < snake gourd (19.91) < cucumber (19.99) < bottle

gourd (20.08) < ridge gourd (20.63) < pumpkin (20.66). The order of hosts on the basis of fecundity (no. of eggs/female) were: bitter gourd (77.50) > snake gourd (63.90) > ash gourd (60.22) > ridge gourd (59.39) > cucumber (57.08) > pumpkin (48.55) > bottle gourd (48.06). The mean length and breadth of the eggs were 1.28 to 1.38 mm and 0.22 to 0.33 mm. The full-grown larvae (maggots) were very mobile and measured 8.92 to 9.66 mm in length and 1.74 to 2.05 mm in breadth.

Akter and Sohel, (2020) studied the biology of the cucurbit fruit fly, *B. cucurbitae* (coq) on bottle gourd, *Lagenaria siceraria*. They reported that the mean incubation period, larval (*1st, 2nd and 3rd* instars), pre-pupal, pupal and total developmental periods of *B. cucurbitae* were 1.69 ± 0.28, (1.72 ± 0.33, 1.41 ± 0.31, 2.31 ± 0.51), 0.74 ± 0.28, 9.2 ± 0.78 and 36 ± 1.69 days. The mean adult longevity, with food and without food was 14.1 ± 1.28 and 5.0±0.81 days. The lengths of all three larval instars were 1.1 ± 0.9, 3.03 ± 0.95 and 6.42 ± 0.90 mm, and the widths were 0.22 ± 0.11, 1.12 ± 0.01 and 2.13 ± 0.20 mm, respectively. The length and width of the pre-pupa and the pupa were 5.86 ±0.48, 5.68 ± 0.26 mm and 1.94 ± 0.23, 2.39 ± 0.20 mm respectively. The length of male and female were 6.61 ± 0.59 and 8.28 ± 0.52 mm. The widths of males and females with wingspan were 10.97 ± 0.43 and 13.02±1.28 mm.

Sowmiya *et al.,* (2021) conducted studies on the biology and morphometry of different life stages of the melon fruit fly, *Zeugodacus cucurbitae* in snake gourd, bitter gourd, and ridge gourd host. Mean length and breadth of the egg (0.66 ± 0.08 mm, 0.13 ± 0.01 mm), first instar (1.10 ± 008 mm, 0.19 ± 0.01 mm), second instar (4.93 ± 0.09 mm, 0.79 ± 0.02 mm), third instar maggot (8.34 ± 0.14 mm, 1.51 ± 0.03 mm), prepupal (6.22 ± 0.11 mm, 1.83±0.06 mm) and pupal period (5.69±0.38 mm, 2.05±0.08 mm) was maximum in bitter gourd host compared to snake gourd and ridge gourd. Similarly mean length and breadth of adult male (5.82 ± 0.07 mm, 10.43 ± 0.11 mm) and female (7.81 ± 0.11 mm, 12.34 ± 0.30 mm) was high in ridge gourd. On Comparing the other hosts, the egg period, first instar, second instar, third instar, prepupa, and pupal period was minimum in bitter gourd 1.45 ± 0.76 days, 0.70 ± 0.25 days, 2.85 ± 0.74 days, 4.3 ± 0.85 days, 0.80 ± 0.25 days, and 8.25 ± 0.82 days, respectively.

2.2 Bio-efficacy of newer insecticides against cucumber fruit fly, *Bactrocera cucurbitae*

Dhillon *et al.,* (2005) studied on melon fruit fly management using local area management and wide area management and reported that the melon fruit fly can successfully be managed over a local area by bagging fruits, field sanitation, protein baits, cue-lure traps, growing fruit fly-resistant genotypes, augmentation of biocontrol agents and soft insecticides.

Oke, (2008) conducted an experiment at the vegetable evaluation and research station at Anse Boileau Mahe Seychelles to test the effectiveness of lambda-cyhalothrine and deltamethrine in controlling melon fruit fly in cucumber. Results showed that both the insecticides were effective in controlling melon fruit fly in cucumber. However lambda - cyahalothrin was found to be better, also it increased the quality of harvested cucumber fruits in relation to the infestation of fruits with ovipositor marks.

Waseem *et al.,* (2009) conducted experiment and recorded observations on the fruit damage of cucumber under field conditions a day before spray revealed that all the treatments including untreated check had fruit damage ranged from 25.30 to 39.00 per cent. Whereas, treatments *viz*., acephate, spinosad, imidacloprid recorded 8.00, 9.00 and 10.33 per cent respectively and were on par with nimbex 0.15%. At 15 days after second spray significantly lowest fruit damage of 2.67 per cent was noticed in nimbex 0.15%, followed by acephate, spinosad, imidacloprid with 4.33, 5.00 and 6.67 per cent fruit damage, respectively and were on par with nimbex 0.15%. The treatments like spinosad, imidacloprid recorded 4.00 and 5.67 per cent damage and were on par with nimbex 0.15%. The highest per cent fruit damage was recorded in untreated check (43.67%). While in the treatments *viz*., indoxacarb, emamectin benzoate and diafenthiuron the damage was 17.67, 19.67 and 32.67 per cent, respectively and were on par with each other.

Sharma and Sinha (2009) evaluated six insecticides, *viz*., alphamethrin, cypermethrin, endosulfan, spinosad, emamectin benzoate and neem baan against *B. cucurbitae* (Coquillett) on bitter gourd during *Kharif*, 2007 and revealed that alphamethrin @ 20 g a.i./ha was most effective and resulted in 5.52 per cent 13

damage as compared to 15.14 per cent in control. Emamectin benzoate @ 15 g a.i. /ha and neem baan @ 1ml/l too were also found effective.

Kate *et al.,* (2010) conducted the experiment on efficacy of various insecticides against fruit fly, *B. cucurbitae* infesting cucumber. Among the nine insecticides tested malathion 0.1% proved to be most effective against fruit fly under field conditions which was at par with fenthion 0.1 %. The fenitrothion 0.03% and alfamethrin 0.005% stood second in order of effectiveness. The highest no of cucumber fruits (8299kg/ha) was recorded in treatment of malathion 0.1% which was at par with fenthion, while fenitrothion 0.03% and alfamethrin 0.005% gave 7648 and 7255kg/ha yield.

Shaikh and Desh (2012) conducted the field experiments to evaluate seven insecticides and biopesticides against fruit flies, *Bactrocera spp*. in cucumber and bitter gourd and reported that abamectin (0.0015%) was the most effective treatment in terms of reducing the fruit infestation as well as number of maggots in both the crops. Lambda-cyhalothrin (0.004%) was the next best treatment followed by azadirachtin (0.0045%) and carbaryl 50 WP (0.20%). However, chlorpyriphos 20 EC (0.05%) and malathion 50 EC (0.05%) were found to be inferior resulting in comparatively less reduction in fruit infestation and number of maggots per infested fruit. From the economic point of view, lambda-cyhalothrin was found a better option resulting in returns of 31.4 and 26.5 at Palampur and 62.9 and 40.6 at Bara (Hamirpur) for cucumber and bitter gourd per rupee invested.

Oke and Sinon (2013) conducted the experiments to evaluate the effectiveness of 3 insecticides namely, lambda cyhalothrin, deltamethrin and mercaptothion to control melon fruit fly in cucumber *B. cucurbitae*. The result obtained showed that use of deltamethrin recorded lowest no of ovipositor marks, no of pupae and melon fruit flies. The no of melon fruit flies that emerged with use of deltamethrin was significally decreased by 19% and 38.1% in 2009 and by 10% and 44.4% in 2010 compared to use of lamda cyhalothrin and mercaptothion. The highest no of marketable cucumbers was produced from plots sprayed with deltamethrin compared with to those obtained when lambda cyhalothrin and mercaptothion were used.

Bhowmik *et al.,* (2014) conducted field trials during 2013 to assess the efficacy of certain chemical treatments against melon fruit fly (*Bactrocera cucurbitae*

Coq.) on bitter gourd. The treatments included deltamethrin @ 10 g *ha*-1, flubendiamide @ 25 g *ha*-1, acephate @ 300 g ha-1, triazophos @ 200 g *ha*-1, cartap @ 250 g *ha*-1, neemazal @ 600 ml *ha*-1, karanja oil @ 1200 mL *ha*-1, citronella oil @ 1200 ml *ha*-1, spinosad @ 60 g *ha*-1, chlorfenapyr @ 50 g *ha*-1 and emamectin benzoate @ 10 g *ha*-1, sprayed thrice at fortnightly interval when the fruit damage ranged between 24.77-29.62% during pre-*kharif* and 25.19-33.59% during *kharif* season. The most effective treatment in reducing the fruit infestation by melon fruit fly was spinosad (5.91%).

Sawai *et al.,* (2014) conducted field experiment to evaluate relative efficacy of different insecticides.The cumulative pooled data of the year 2011 and 2012 pertaining to the fruit damage by fruit fly revealed that treatment deltamethrin (0.0016 %) recorded significantly the lowest (20.15 %) fruit damage, however it was statistically at par with DDVP (0.05 %), emamectin benzoate (0.0016 %) and azadirachtin (0.0025 %) with 22.83, 24.05 and 24.79 % fruit damage, respectively. The highest marketable yield was obtained in treatment of deltamethrin (20.95 ha-1) which was significantly more than rest of the treatments except DDVP (19.96 t ha-1), whereas, DDVP was also found at par with emamectin benzoate.

Khatun *et al.,* (2015) conducted the experiment and in this study, abamectin, emamectin benzoate, lufenuron and lambda-cyhalothrin were evaluated against the *B. cucurbitae*. Abamectin was applied alone and in combination with the others. A total of two sprays were given and data on per-cent fruit infestation, number of marketable fruit/m^2, infested and marketable fruit yield (t/ha) were collected on 3, 7 and 10 DAT. All the combined treatments significantly reduced per-cent fruit infestation. The highest infestation was observed in control ranged from 12.07 to 67.61%. Abamectin significantly reduced the fruit infestation (16.81%) compared to control which was further reduced in abamectin plus lambda-cyhalothrin (13.40%) treatment.

Khatun *et al.,* (2016) conducted the field experiment on bitter gourd using efficacy of two bacterial fermented bio-pesticides (abamectin and emamectin benzoate), one insect growth regulator (lufenuron) and one newer pyrethroid (lambda-cyhalothrin) against cucurbit fruit fly, *B. cucurbitae* (Coquillett). In experiment two concentrations of the selected bio-pesticides were tested. A total of three sprays were applied and data were collected on different parameters *viz.* per-cent fruit infestation,

number of marketable fruits/m^2, infested and marketable fruit yield (t/ha) *etc*. Analysis of the results revealed that abamectin (Ambush 1.8 EC) was found as the most effective one followed by emamectin benzoate (Suspend 5 SG) while the insect growth regulator, lufenuron (Haron 5 EC) was found as less effective against the *B. cucurbitae* based on the parameters studied.

Patil (2016) studied seasonal incidence of major insect pests of cucumber. The insect pests which caused maximum yield losses in cucumber were aphid, *Aphis gossypii,* Whitefly, *Bemisia tabaci,* Leaf miner. Peak incidence of aphids (48.50 aphids/3 leaves), whitefly (3.28/3 leaves), leaf miner (4.08/leaf), lady bird beetle (4.08/leaf) and syrphid fly (3.92/leaf) was recorded during 33^{th} MW, 31^{st} MW, 36^{th} MW, 34^{th} MW, 37^{th} MW, respectively. Bio-efficacy studied on major sucking pests complex indicated that cynantraniliprole 10.26 OD proved to be the best treatment showing maximum reduction of aphid, whitefly, leaf miner population.

Sunil *et al.,* (2016) conducted field experiments to evaluate the efficacy of selected insecticides against melon fruit fly, *B. cucurbitae* in bitter gourd, they revealed that deltamethrin 2.8 EC + jaggery bait (0.0028 + 0.015 %) was the most effective treatment resulting in minimum fruit infestation (13.15%, 8.61%), as well as lowest number of maggots per fruit (12.58, 9.58). The next superior treatment was deltamethrin 2.8 EC (0.0028 %), azadirachtin 1 EC (0.005 %) and malathion 50 EC (0.1 %) which were on par in terms of reduction of fruit infestation. However, spinosad 45 SC (0.014 %) and dichlorovos 76 SC (0.152 %) were found to be inferior with comparatively lesser reduction in fruit infestation as well as number of maggots per infested fruit as compared to the other treatments, except untreated control.

Bharadiya and Bhut (2017) conducted field experiments on effect of different insecticides against fruit fly, *Bactrocera cucurbitae* Coquillett infesting sponge gourd. The five different insecticides were evaluated against the fruit fly, *B. cucurbitae* infesting sponge gourd. The insecticides abamectin 0.0025 per cent and emamectin benzoate 0.002 per cent were found most effective and economical and were statistically at par with each other.

Lekha and Swami (2017) conducted field experiment on the bio-efficacy of different bio-intensive treatment modules against cucurbit fruit fly, *B. cucurbitae* in cucumber. The results revealed that among eight spray combinations of biopesticides

viz., spinosad (200ml/ha), azadirachtin (0.03%) and NSKE (5%), three sprays of spinosad (200ml/ha), first spray applied as soon as the ovipositor marks were seen on the fruits and subsequent sprays at an interval of twelve days proved to be the most effective treatment module in controlling the fruit fly with least mean number of fruits with ovipositor marks (1.50), mean number of pupae of fruit fly formed from damaged fruits (5.92) and mean per cent fruit infestation (8.28 per cent) and avoiding maximum losses up to 56.88 per cent with highest fruit yield (555.56 q/ha). The treatment module comprising two spray applications of spinosad (200 ml/ha) followed by a spray of azadirachtin (0.03%) was the next effective treatment.

Kumar and Shankar (2017) conducted field experiment and recorded that after five days of 1^{st} spray, the maximum reduction of whitefly population was due to application of spinosad (57.87 %). This was followed by application of oxydemeton methyl in various plots (45.10 %), thiamethoxam, imidacloprid (21.14) and carbaryl (19.63 %). The field bio-efficacy of the treatments was evaluated and found that after two sprays of spinosad were effective in suppressing the population of whiteflies in the field.

Balas *et al.,* (2018) conducted investigation on comparative efficacy of different insecticides against fruit fly *B. cucurbitae* on cucumber during *kharif* season. They revealed that among the results of two sprayings of fipronil, dichlorvos, polytrin C, profenophos, spinosad, lambda - cyhalothrin, malathion, clorantranliprole and bifenthrin insecticides against the cucumber fruit fly, dichlorovos @ 0.05 %, lambda cyhalothrin 0.005 %and alathion @ 0.1 % were found more effective treatments against to pest compared to other insecticides.

Hirekurubar and Tatagar (2018) conducted field experiment to evaluate the bio-efficacy of different insecticides (profenophos, buprofezin, spinosad, chlorantraniliprole, thiamethoxam, acephate, malathion) along with aqueous NSKE @ 5 % and azadiractin 1500 ppm against leaf miner, *Liriomyza trifoii* (Burgess) on ridge gourd. The results of pooled data revealed that spinosad 45 SC @ 0.3 ml/l was most effective in reducing leaf minor fallowed by chlorantraniliprole 18.5 SC @ 0.20 ml/l and thiamethoxam 25 WG @ 0.25 g/l. The highest yield was recorded in spinosad.

Srinivas *et al*., (2018) conducted the field experiment on effect of different insecticides against fruit fly *B. cucurbitae* infesting cucumber during *kharif* 2017 and

summer 2018. The results revealed that lowest no of ovipositional punctures (0.72 and 0.98/ fruit) maggots (8.0 and 8.93/fruit) fruit infestation (14.92 and 17.90%), highest marketable fruit yield (15.63 and 16.49 t/ha) and more cost benefit ratio was recorded in treatment with spinosad 45 SC (0.15 ml/l) during both season. It was on par with treatment dichlorvos 76 EC (1.0 ml/l) however highest number of ovipositional punctures (2.72 and 3.01 per fruit), highest number of maggots (19.13 and 19.80 per fruit) highest percentage of fruit infestation (46.91 and 56.79 %) lowest marketable fruit yield (10.75 and 9.1 t/ha) was obtained in jaggery treatment (10 gm/l) followed by control in both *Kharif* and *Summer* season.

Shinde *et al.,* (2018) carried out the field experiment to evaluate bio-efficacy of insecticides against fruit flies infesting cucumber. The results on efficacy of insecticides against fruit flies infesting cucumber indicated that spinosad 45 SC @ 0.014 per cent was the best treatment which recorded minimum (15.38%) mean fruit infestation and was at par with emamectin benzoate 5 SG @ 0.002 per cent (20.49%). The next best treatments were azadirachtin (1%) @ 0.003 per cent (27.99%) and malathion 50 EC @ 0.05 per cent (32.89%) which were at par with each other. Similarly, malathion 50 EC @ 0.05 per cent (32.89%) which was at par with deltamethrin 2.8 EC @ 0.0024 per cent and dichlorvos 76 EC @ 0.05 per cent recorded 37.32 and 38.99 per cent fruit infestation, respectively.

Nehra *et al*., (2019) carried out field experiment on the bio-efficacy of newer insecticides and biopesticides against fruit fly, *B. cucurbitae* (Coquillett) on round gourd. Among the insecticides evaluated on round gourd, spinosad was found most effective. The next effective treatments were acephate + molasses followed by acephate and fipronil. The treatments of Neem Gold and NSE were found least effective. 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) whereas; minimum (50.12 q *ha*-1) was in NSE.

Sharma and Gupta (2019) conducted field experiment to study the efficacy and monetary returns of different new insecticides against fruit flies. The results of the bio-efficacy study revealed lambda-cyhalothrin @ 0.004% with least fruit infestation (17.13%) as the most effective insecticide in checking the fruit fly population which was followed by emamectin benzoate @ 0.002% (24.64% infestation). Also, the

maximum avoidable loss (65.57%) was recorded in lambda-cyhalothrin followed by emamectin benzoate (61.11%) treated plots which proved their efficiency in managing fruit flies.

Sharma and Gupta (2019) conducted field experiment to evaluate efficacy of insecticides and biopesticides against *Bactrocera* spp. infesting cucumber, they revealed that lambda cyhalothrin (0.008%) was the most effective insecticide, with infestation values of 13.59 and 11.69 per cent, during 2014 and 2015, respectively. It was followed by the same insecticide at lower concentration (0.004%) where, fruit infestation of 19.52 and 16.13 per-cent were recorded during 2014 and 2015. Spinosad (0.004 and 0.002%) was next in the order of effectiveness with fruit infestation values of 25.41, 23.69 and 28.45, 25.85 per- cent, during 2014 and 2015 and was at par with fruit infestation of 15.48 and 24.15 per cent in deltamethrin (0.0056%).

CHAPTER – III

MATERIALS AND METHODS

CHAPTER-III

MATERIAL AND METHODS

The field and laboratory experiment on biology and management of cucumber fruit fly *Bactrocera cucurbitae* (conquillett) was conducted during *Summer* 2020-2021. The materials used and methods adopted for recording observations during the course of investigation are described in this chapter under following sub heads.

3.1 Location of the experiment

Field experiment was conducted during *Summer* 2020-2021 at the Research Farm of Department of Agril. Entomology, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani (Maharashtra), which is situated 190 16' North Latitude and 760 47' East Longitudes with an altitude of 408.50 meter above mean sea level.

3.2 Climatic conditions

The mean annual rainfall of Parbhani is about 800-900 mm receiving mostly during June to September. *Summer* is hot and dry while winter is cool. The mean daily maximum temperature varies from 29.4°C in December to 45°C in May. The minimum temperature varies from 11.32°C (winter) to 25.77°C (*Summer*). The mean relative humidity ranges from 30 to 90 per cent with subtropical climate.

3.3 Soil type

The experiment was conducted on well drained typical black cotton soilwith uniform level of fertility. The depth of the soil was 2 to 3 meters.

3. 4 Experimental materials

The agricultural implements required for preparatory tillage, various inputs such as fertilizers, seeds of cucumber, labels, threads, plastic boxes, wooden sticks, polythene bags, insecticides, measuring cylinders, knapsack sprayer, buckets, weighing balance *etc.* and materials used for biological studies *viz.* glass jars, honey, muslin cloth, petri- dishes, plastic oviposition cages, filter papers, camel hair brush, hand lens have been obtained from Department of Agricultural Entomology,

Vasantrao Naik Marathwada Krishi Vidyapeeth Parbhani.

3.5 Agronomic practices

3.5.1 Land preparation

The land was prepared by ploughing, clod crushing, harrowing and was brought to the fine tilth, then field was cleaned by collecting the stubbles. Fine beds were prepared and experimental plot was laid out as per statistical design.

3.5.2 Layout of experiment

Field experiment was laid out in Randomized Block Design with eight treatments replicated thrice. The gross plot size was 3.6 m x 2.1 m and spacing was 1.2 m x 0.45 m.

3.5.3 Sowing

Marking of lines was done by wooden marker at 1.2 m spacing. Sowing of experimental plot was done on 15th January 2021 by dibbling 2 seeds per hill at the depth of about 4-6 cm at a distance of 0.45 m and then covered with soil carefully.

3.5.4 Gap filling and thinning

Gap filling was done at 7th day after emergence and thinning operation was performed at 10 days after emergence of the crop and only one healthy seedling was kept at each hill.

3.5.5 Application of fertilizers

The recommended dose of fertilizers 100:50:50 N, P and K kg per hectare was applied. Half dose of N and full dose of P and K was applied at the time at sowing. Remaining half dose of nitrogen was applied after one month.

3.5.6 Hoeing and weeding

Timely hoeing and weeding operations were carried out to remove weeds to improve the soil aeration and conserve the soil moisture.

3.6 Biology of cucumber fruit fly, *Bactrocera cucurbitae*

The studies on biology of fruit fly, *Bactrocera cucurbitae* (C.) infesting cucumber was carried out on single host crop for the pest in the laboratory of Department of Agricultural Entomology, Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani.

3.6.1 Rearing Technique:

Initial cultures of fruit flies were raised by collecting infested fruits from the plots of cucumber crops from Research Farm of Department of Agril. Entomology, VNMKV, Parbhani. The infested fruits were kept in plastic jars (diameter 15 cm and height 20 cm) containing 5 cm thick layer of sieved sand at bottom of jar to obtain pupae. The top of the jar was covered with clean white muslin cloth duly tightened with rubber band to prevent the maggots from escaping.

Such jars were used for maintaining the culture of fruit fly, *Bactrocera cucurbitae* (C.) when all the full-grown maggots entered in the sand for pupation, the rotted fruits were removed from the container. After 4-5 days, the sand in the container was sieved to collect pupae. The pupae were transferred in glass tubes (1.5 cm diameter, 7.5 cm height), individually. The tubes were plugged with cotton lint to prevent the escaping of adult fruit flies when emerged. The flies emerged wereutilized for further studies on life history.

The freshly emerged adults were paired and confined in the plastic jars (diameter 15 cm, height 20 cm) covered with a white muslin cloth bag. On end of the bag was kept open for introducing the adults into the jar. The open end of the bags was tightened with rubber band to prevent the adult from escaping. Such jars were kept in the wooden cages (68 x 53 x 37 cm) to prevent the damage from ants and rodents. A cotton swab with 5 per cent sugar solution was suspended inside the jar as food to the adult flies. Premature uninfected fruits were placed inside the jar for oviposition. The fruits were replaced after observing the punctures. The fruits punctured due to egg laying in cut open with a fine razor blade and egg laid if and confirmed using magnifying lens. About 2 x 1 x 1 cm sized piece of fruit having eggs were smoothly cut and transferred in a separate petri dish and was observed twice a day for their hatching. Eggs were carefully transferred with a fine camel hair brush

(No. 1) on a glass slide and observed under microscope to study their morphometric characters.

After hatching of eggs, the neonate maggots were gently transferred on a fresh fruit slice (2 x 2 x 1 cm) later kept in petri dish for further rearing. The food (fruit slice) as well as petri dishes were changed every day to avoid microbial development on fruit slice. The maggots were reared following this method until they were full grown and transferred along with petri dish in a small plastic jar (diameter 15 cm, height 20 cm) filled with a layer of 5 cm sand. The jars were covered with muslin cloth and tightened with rubber bands for preventing the escaping of maggots.

3.6.2 Pre-oviposition, oviposition and post-oviposition period:

The pre-oviposition period on fruits was calculated from the date of emergence of female to the date of starting of egg laying. The oviposition period was calculated from the time and date of starting of egg laying to the time and date of ceasing of egg laying. The post-oviposition period was calculated from the date of ceasing of egg laying to the death of female.

3.6.3 Fecundity:

The number of eggs laid on fruits by each female were recorded till egglaying stops and average fecundity was calculated.

3.6.4 Egg:

Eggs were observed under the microscope for studying their colour, shape and size. Similarly, for measurements the eggs were gently transferred under compound microscope with the help of moist hair brush. The microscope was calibrated with stage and ocular micrometer before measuring the eggs. Incubation period was studied by keeping known number of freshly laid eggs in fruit slice by making a small hole with the help of sharp pointer and observed daily in the morning and evening till hatching. The eggs were considered as hatched, when the tiny maggots came out from it, whereas hatching percentage was calculated from the number of eggs hatched out of total number of eggs kept under observation.

3.6.5 Maggot (Larva):

A thick (2 cm) slice of fruits was kept individually in a petri dish. It was slightly ruptured with the help of scalpel for easy entry of the maggot. The newly hatched maggots were transferred individually on fruit slice. The maggots were reared till they underwent for pupation. The food was changed every morning to maintain the sanitation in the petri dish. The first instar (newly hatched) and fully grown maggots were observed under microscope for studying the shape, size and colour.

3.6.6 Pre-pupa:

A stage, when full grown maggots ceased feeding and became inactive was considered as pre-pupal stage. These maggots were transferred with food to plastic jar (diameter 15 cm, height 20 cm) with 5 cm layer of sieved sand at the bottom for pupation. The observations on shape, size and colour of pre-pupal stage were recorded. The breadth and length of pre-pupal stage was measured under microscope. The pre-pupal period was recorded for individual maggot reared on fruits.

3.6.7 Pupa:

The pupal period was calculated from the date of formation of pupa to the date of emergence of the adult from the pupa. The pupae was studied for their shape, size, colour and period. The breadth and length was also measured.

3.6.8 Adult:

The newly emerged adults from fruits were critically observed under microscope for their size, shape, colour and sex differences. The breadth and length of adults was also measured.

3.6.9 Sex Ratio:

Sex ratio was studied and pupae were kept in a plastic jar on the layer 5 cm sieved sand and jar was covered with white muslin cloth fixed with a rubber band to prevent the escape of adults. The sex ratio was calculated by separating the males and females, based on their morphological characters.

3.6.10 Longevity:

The longevity of male and female was calculated separately from the date of emergence to the death of adult.

3.6.11 Total Life Cycle:

The period from eggs laid to the death of adult was considered as the total life cycle.

3.7 Bio-efficacy of newer insecticides against Cucumber fruit fly, *Bactrocera cucurbitae*

A field experiment on bio-efficacy of different insecticides against insect pests of cucumber was carried out at the Research Farm of Department of Agricultural Entomology, VNMKV, Parbhani during *Summer* 2020-21.

3.7.1 Preparation and application of insecticidal spray

The measured quantity of insecticide was added in three liter of water and thoroughly mixed with stick. The desired concentration of spray solution was prepared by using formula.

Where,

$$V = \frac{C \times A}{\%\ a.i.}$$

V = volume of commercial insecticides in ml,

C = concentration of spray solution required,

A = quantity of spray solution required in ml,

% a.i. = percentage of active ingredient in commercial product

The insecticidal spray mixture of respective treatment was freshly prepared every time at the site of experiment just before spraying. The sprayings were undertaken after appearance of pest. Two sprayings were administered on 16th march and 01st April 2021.

3.7.2 Experimental Details

Season	:	*Summer* 2020-2021
Design	:	Randomized Block Design (RBD)
Treatments	:	Eight (8)
Replications	:	Three (3)
Crop	:	Cucumber
Variety	:	Gipsy (Pyramid seeds)
Spacing	:	1.2 m x 0.45m
Plot size	:	3.6 m x 2.1m
Number of plots	:	24
Fertilizer Dose	:	100:50:50 NPK kg/ha
Date of sowing	:	15 January 2021

3.7.3 Treatment details:

Tested insecticides.

Sr. No	Name of Treatment	Insecticide (gm/ml) in 10 lit. water	Tradename	Company name
T_1	Emamectin benzoate 5 SG	4/ml	Proclaim	Syngenta
T_2	Flubendiamide 480 SC	2.5/ml	Fame	Byer
T_3	Spinosad 45 SC	3/ml	Tracer	Dow
T_4	Cyantraniliprole 10 SC	8/ml	Benevia	FMC
T_5	Novaluron 10 EC	7.5/ml	Rimon	Indofil
T_6	Lambda cyhalothrin 5 EC	8/ml	Karate	Syngenta
T_7	Chlorantraniliprole 18.5 SC	3/ml	Coragen	FMC
T_8	Untreated control	--	--	--

3.7.4 Application of treatments:

The insecticides were tested and compared control wherein only water was sprayed. The desired concentrations were prepared with in water and sprayed with the help of knapsack sprayer in experimental crop. Two sprays of each insecticide were applied at an interval of 15 days in each experimental plot.

3.7.5 Method of recording observations:

Melon fruit fly: To evaluate efficacy of different insecticides, total fruit count was taken in treated as well as control plots. From the total fruits, infested fruits/plot were counted and computed to work out the per cent fruit damage. Fruit yield/plot was recorded after application of insecticide treatments at an interval of 15 days. The observation were recorded at 3, 7 and 14 days after spraying.

The damaged and healthy fruits were sorted out at each picking and observations on per-cent fruit infestation was taken on number basis which is subjected to arc sin transformation and was statistically analyzed by following RBD. The yield of fruits was recorded from net plot area of each treatment and converted to hectare basis and then statically analyzed. Thus, the data obtained was transformed into arc sin transformation before statistical analysis.

$$\text{Per-cent fruit damage} = \frac{\text{Total damaged fruits}}{\text{Total fruits}} \times 100$$

Economics of all treatment was worked out by considering the price of products, cost of insecticides and labour charges. Cost benefit ratio (CBR) was also worked out to compare the economics of different insecticidal treatments.

$$\text{Incremental cost: benefit ratio (ICBR)} = \frac{\text{Net realization (Rs/ha)}}{\text{Total cost of insecticides (Rs/ha)}}$$

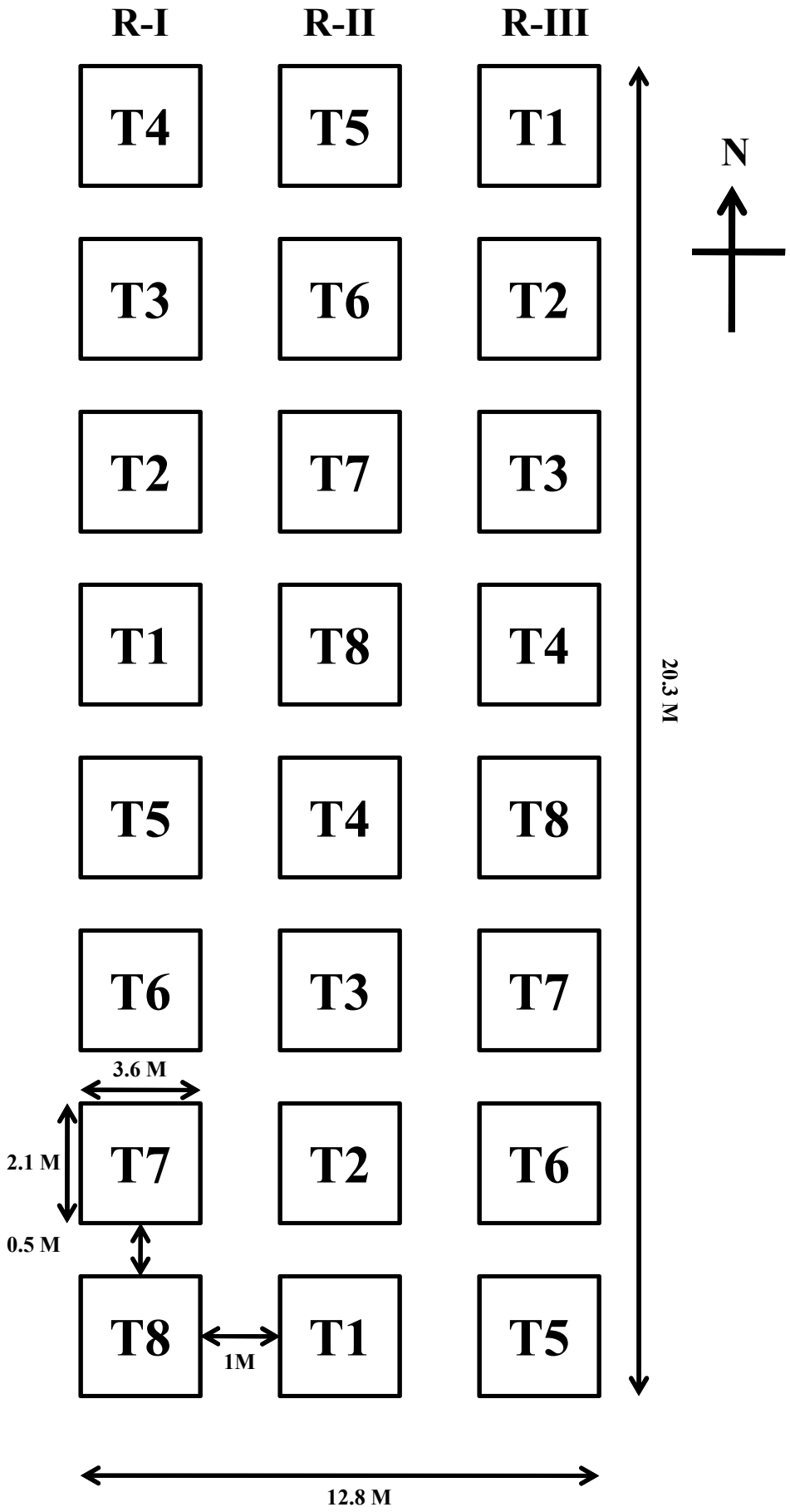

Fig. No. 3.1. Plan of Layout and experimental design

Plate. No. 3.1 Experimental field

CHAPTER – IV

RESULTS AND DISCUSSION

CHAPTER IV

RESULTS AND DISCUSSION

Result of investigations of biology and bio-efficacy of different insecticides against fruit fly *Bactrocera cucurbitae* (Coquillett) on cucumber was carried out during *Summer* 2020-2021 at Department of Agriculture Entomology, VNMKV Parbhani and presented under following heads.

1. To study the biology of cucumber fruit fly, *Bactrocera cucurbitae*

2. To study the bio-efficacy of newer insecticides against cucumber fruit fly, *Bactrocera cucurbitae*

4.1 To study the biology of cucumber fruit fly, *Bactrocera cucurbitae*

The biology of cucumber fruit fly, *Bactrocera cucurbitae* (Coquillett) was studied under laboratory condition and data is presented in (Table-4.1, 4.2 & 4.3).

4.1.1 Incubation period

The present findings revealed incubation period ranging from 12 to 24 hours with a mean of 17.9 ± 3.62 hours (Table-4.1).

The present findings are closely conformity with Gaddanakeri and Rolania, (2020) who reported that the incubation period ranged from 12 – 24 hours with mean 18.0 ± 6.32 hours reared on bitter gourd.

4.1.2 Maggot period

Three larval instars were observed during the growth of *B. cucurbitae* larvae. The duration of first, second and third instar larvae reared on cucumber was ranged between 0.5-1.0, 1.5-2.5 and 2-3 days, respectively. The average duration of first, second and third instar maggot was 0.75 ± 0.15, 1.89 ± 0.32 and 2.43 ± 0.33 days, respectively. The total maggot period was 5.07 ± 0.42 days with range of 4-6.5 days (Table – 4.1).

The result are more or less in direction of the result of experiment conducted by Gaddanakeri and Rolania, (2020) who reported that total maggot period 5.80 ±

0.78 with range of 5 to 7 days. They observed the range of first, second and third instar larvae as 0.5-1.0, 1.5-3 and 2-3 days with average of 0.8 ± 0.26, 2.0 ± 0.53 and 2.55 ± 0.44 days respectively reared on bitter gourd.

Table 4.1 : Durations of different life stages of *B. cucurbitae* reared on cucumber

Stage		Range	Mean ± SD
Egg (Incubation period) (hours		12-24	17.9 ± 3.62
Maggot period (days)			
1st Instar		0.5-1.0	0.75 ± 0.15
2nd Instar		1.5-2.5	1.89± 0.32
3rd Instar		2-3	2.43 ± 0.33
Total maggot period (days)		4-6.5	5.07 ± 0.42
Prepupal period (days)		0.5-1	0.77 ± 0.14
Pupal period (days)		8-9	8.35 ± 0.45
Mating period (hours)		2-4	3.3 ± 0.78
Pre-oviposition period (days)		10-15	12.3 ± 1.55
Oviposition period (days)		2-4	2.65 ± 0.72
Post-oviposition period (days)		1-3	2.05 ± 0.66
Fecundity		53-87	71.9 ± 11.41
Hatching percentage		81-86	83.3 ± 1.68
Sex ratio (Male:Female)		0.90:1.20	1.07 ± 0.09
Total life period	**Male**	27-43	34.6 ± 4.29
	Female	30-46	38.35 ± 4.77

* Each data point is the mean of 20 observations

4.1.3 Prepupal and Pupal period

The prepupal period ranged between 0.5 to 1 day with its mean 0.77± 0.14 days. Whereas, pupal period ranged between 8 to 9 days with mean of 8.35± 0.45 days on cucumber fruit fly, *B. cucurbitae* under laboratory conditions (Table-4.1).

The present result is with the finding of Mir *et al*, 2014 who recorded 0.5-1.0 days pre pupal period with average of 0.8 ± 0.25 days and pupal days ranged between 8 to 9 days with mean duration of 8.4 ± 0.25 days.

4.1.4 Mating period

During mating the female bobbed the abdomen and ovipositor in the presence of male and tilted the abdomen and ovipositor up sharply while approaching the male. Male lunged at female while vibrating the wings, sometimes followed by the male mounting the female. Most mountings began with the male placing fore tarsi on the head of the female and then aligning body somewhat parallel to the female before climbing onto thorax. The male then moved posteriorly while on the torso of the female until contact was made between genitalia and the tip of oviscape. To bring the tip of the oviscape into position, the male grasped the distal part of the oviscape with hind legs and pulled the oviscape forward while moving posteriorly on the female. The male phallus was inserted into the distal tip of the aculeus and was extended to the base of the ovipositor where sperm was deposited in the vicinity of the vagina, where the spermathecal ducts join the common oviduct. The copulation lasted for a minimum of 2 hours to maximum of 4 hours with mean of 3.3 ± 0.78 (Table – 4.1).

The present result confirmity with the finding of Mir *et al*, 2014 who recorded mating period of 2 to 4 hours with mean of 3.5 ± 0.84 hours.

4.1.5 Pre-oviposition, oviposition and post-oviposition period

The pre-oviposition, oviposition and post-oviposition period ranged between 10 to 15 days, 2 to 4 days and 1 to 3 days with average of 12.3 ± 1.55, 2.65 ± 0.72 and 2.05 ± 0.66 days, respectively (Table-4.1).

The results are almost similar to the findings of Patel and Patel (2018) who reported range of 10-12, 2-4 and 1-3 days with mean of 11.00 ± 0.667, 2.80 ± 0.632 and 1.60 ± 0.699 days of pre-oviposition, oviposition and post-oviposition periods, respectively which was reared on bitter-gourd.

4.1.6 Total Life Cycle

The period from egg to death of adult male ranged between 27-43 days with mean of 34.6 ± 4.29 days, whereas female ranged between 30-46 days with average of 38.35 ± 4.77 days (Table-4.1).

These results are in accordance with Gaddanakeri and Rolania, (2020) who reported life period of male with range of 30-46 days mean of 36.2 ± 5.77 days and

life period of female with range of 32-50 days mean of 40.4 ± 6.24 days.

4.1.7 Fecundity

The number of eggs laid by female ranged from 53-87 with mean of 71.9 ± 11.41 (Table-4.1).

The results are according to Mir *et al*, 2014 who reported fecundity range of 58-92 with mean of 75.8 ± 12.49.

4.1.8 Hatching percentage (%)

Hatching percentage ranged between 81-86 with mean of 83.3 ± 1.68 (Table-4.1). The present results are close to the findings of Mir *et al*, 2014 who reported hatching percentage range between 83-88 with mean of 86.1 ± 0.54.

4.1.9 Sex Ratio (Male : Female)

The adults emerged from pupae were critically examined and sexed by observing presence or absence of pointed ovipositor. Sex Ratio (Male:Female) ranged between 0.90 to 1.20 with average of 1.07 ± 0.09 (Table-4.1).

The present results are same in according with the findings of Mir *et al*, 2014 who reported sex ratio (Male:Female) ranged between 0.95 -1.25 with mean of 1.10 ± 0.14.

4.1.10 Morphological and morphometric observations on *B. cucurbitae*

Morphometric study of different life stages of *B. cucurbitae* was carried out by taking twenty replicates of each stage *viz.* egg, maggot, prepupa, pupa and adult for linear measurements.

4.1.10.1 Egg

According to the observations, the eggs of *B. cucurbitae* were slightly curved, elongated and tapering at one end while rounded at other end. The colour of freshly laid eggs was glistering white. The average length and breadth of eggs were 1.12 mm ± 0.09 mm and 0.22 mm ± 0.04 mm with range of 0.93 mm -1.25 mm and 0.16 mm-0.29 mm respectively (Table-4.2; plate- 4.1 -A).

Plate-4.1: (A) Eggs (B) 1st (C) 2nd (D) 3rd instar maggots of *B. cucurbitae*

Gaddanakeri and Rolania, (2020) who reported mean length and breadth of eggs 1.22 mm ± 0.07 mm and 0.23 mm ± 0.04 mm, with range of 1.12 mm to 1.34 mm and 0.16 mm to 0.28 mm, respectively which was reared on bitter-gourd, confirms the findings of present investigation.

4.1.10.2 Maggot

The apodous maggots develop through three instars. The hatching of the eggs was observed in different times in the day. Freshly emerged first instar maggots were translucent and white in colour, whereas second instar maggots were translucent, elongate, ellipsoidal in shape and creamy white in colour. The first and second instar maggot measured on an average 1.60 ± 0.24 and 6.41 ± 0.81 mm in length and 0.27 ± 0.05 and 1.18 ± 0.09 mm in breadth, with range of 1.12 mm to 1.87 mm and 4.82 mm to 7.74 mm in length and 0.17 mm to 0.34 mm and 1.01 mm to 1.30 mm in breadth respectively. The full grown third instar maggot was found to be twelve segmented with first segment being largest with a conspicuous dark transverse line extending between intermediate areas of caudal segment. It exhibited a peculiar habit of springing in air, which was performed by curving and tightly seizing the posterior end of the body with the help of special oral hooks and their sudden release. Average length and breadth of full grown maggot was 9.43 ± 0.79 and 2.06 ± 0.32 mm, with range of 8.19 mm to 10.60 mm in length and 1.68 mm to 2.67 mm in breadth, respectively (Table-4.2; Plate-4.1 B, C & D).

The present results are confirmed by Mir *et al.,* 2014 who revealed that the mean length and breadth of first instar maggot was 1.49 mm ± 0.28 mm and 0.31 mm ± 0.07 mm with range of 1.17 mm-1.92 mm and 0.22 mm-0.39 mm, respectively. The mean length and breadth of second instar maggot was 6.40 mm ± 0.86 mm and 1.21 mm ± 0.09 mm with range of 4.87 mm – 7.49 mm and 1.06 mm-0.35 mm, respectively. The mean length and breadth of third instar maggot was 9.62 mm ± 0.87 mm and 2.05 mm ± 0.32 mm with range of 8.24 mm – 10.65 mm and 1.73 mm-2.72mm, respectively.

Table 4.2 : Morphometrics of different life stages of *B. cucurbitae* reared on cucumber

Stage	Adult longevity (days)			
	Length (mm)		Breadth (mm)	
	Range	Mean ± SD	Range	Mean ± SD
Egg	0.93-1.23	1.12 ± 0.09	0.16-0.29	0.22 ± 0.04
Maggot				
1st instar	1.12-1.87	1.60 ± 0.24	0.17-0.34	0.27 ± 0.05
2nd instar	4.82-7.74	6.41 ± 0.81	1.01-1.30	1.18 ± 0.09
3rd instar	8.19-10.60	9.43 ± 0.79	1.68-2.67	2.06 ± 0.32
Prepupa	6.17-6.65	6.42 ± 0.15	1.93-2.1	1.98 ± 0.05
Pupa	5.41-5.86	5.65 ± 0.14	2.27-2.63	2.43 ± 0.11
Adult (with expanded wings)				
Male	8.00-8.69	8.54 ± 0.13	9.95-12.64	11.43 ± 0.95
Female	9.45-9.97	9.82 ± 0.15	14.83-16.85	15.82 ± 0.63

*All measurements are the means of 20 observations.

4.1.10.3 Pre-pupa

The observations revealed that prepupa was slightly bent in position, became sluggish and stopped feeding. Average length and breadth of prepupa was 6.42 ± 0.15 mm and 1.98 ± 0.05 mm, with range of 6.17 mm to 6.65 mm in length and 1.93 mm to 2.1 mm in breadth, respectively. (Table-4.2; Plate-4.2, A).

These findings are in conformity with the findings of Gaddanakeri and Rolania (2020) who worked on bitter-gourd and reported that the mean length and breadth was 6.41 mm ± 0.15 mm and 2.03 mm ± 0.04 mm with range of 6.25 mm-6.54 mm and 1.98 mm – 2.08 mm, respectively.

4.1.10.4 Pupa

The freshly formed pupa was cream coloured which turned light brown to dark yellow within 4-5 hours. The pupae were barrel shaped, distinct eleven segmented with a single black dot on posterior portion and also a dark transverse line across the middle of posterior end (as present in maggot). The average length and

Plate-4.2: (A) Prepupa (B) Pupa and (C) adult emerging from pupa of *B. cucurbitae*

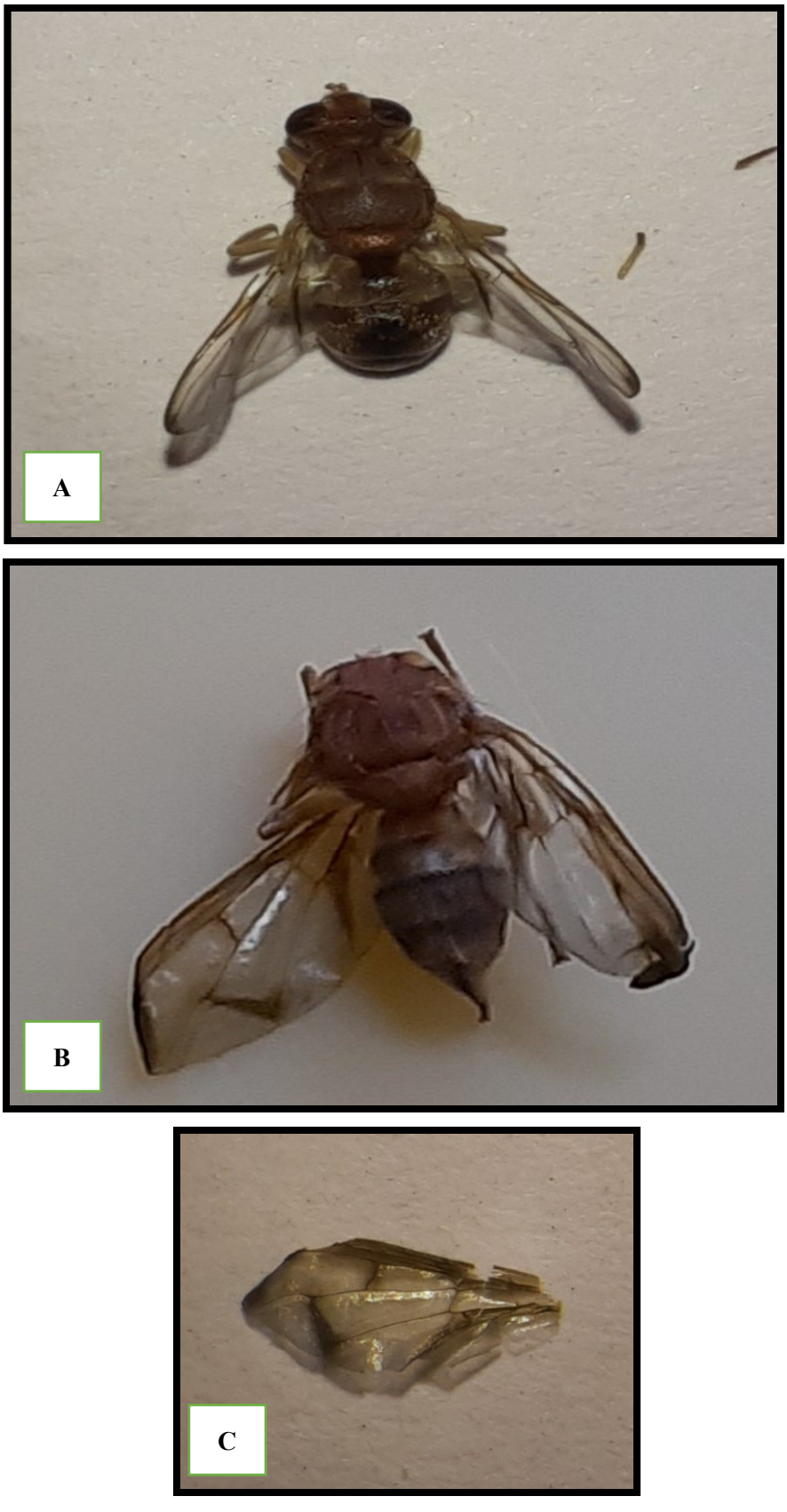

Plate-4.3: (A) Adult male (B) Adult female and (C) wing showing venation of *B. cucurbitae*

breadth of pupae were 5.65 mm ± 0.14 mm and 2.43 mm ± 0.11 mm, with range of 5.41 mm to 5.86 mm and 2.27 mm to 2.63 mm, respectively (Table 4.2; Plate-4.2, B).

These findings are in conformity with the findings of Gaddanakeri and Rolania (2020) who reported that the mean length and breadth was 5.98 mm ± 0.38 mm and 2.54 mm ± 0.14 mm with range of 5.30 mm-6.45 mm and 2.35 mm – 2.72 mm, respectively.

4.1.10.5 Adult

The teneral adults were less active, pale yellow with wings attached to body and took 25-35 minutes to gain a fly look. The flies attained its normal reddish-brown colour with lemon yellow curved vertical markings on the thorax and fuscous shadings on the outer margin of the wings. Wing margin had a large apical spot which is formed by the expansion of posterior cross vein. Adults were moderate in size; female flies were bigger than males and easily distinguished by the presence of a tapering abdomen ending in a pointed ovipositor. The average length and breadth (with expanded wings) of male was 8.54 mm ± 0.13 mm and 11.43 mm ± 0.95 mm, with range of 8.0 mm to 8.69 mm and 9.95 mm to 12.64 mm, respectively. whereas, the female measured on an average 9.82 mm ± 0.15 mm in length and 15.82 mm ± 0.63 mm in breadth (with expanded wings) with range of 9.45-9.97 mm and 14.83-16.68 mm, respectively (Table-4.2; Plate- 4.3 A&B).

The findings were related to Mir *et al.,* 2014 who reported the average length and breadth (with expanded wings) of male was 8.74 mm ± 0.32 mm and 11.46 mm ± 0.16 mm, with range of 8.05 mm to 8.74 mm and 10.00 mm to 12.69 mm respectively. Whereas, the female measured on an average 9.94 mm ± 0.20 mm in length and 15.92 mm ± 0.74 mm in breadth (with expanded wings) with range of 9.50 mm-10.2 mm and 14.88 mm-16.90 mm, respectively.

4.11 Adult Longevity

Average longevity was calculated of adult male and female flies fed on different food sources. When adult male and female fed on water only mean longevity observed was 22.8 **±** 5.58 and 22.2 **±** 4.81 with range of 12-32 days and 14-30 days, respectively. When fed on water and honey (1:1) mean longevity observed was 2.7 **±** 0.40 with range of 2-3 in male and 3.4 **±** 0.44 with range of 3-4 in female.

When no food or water was given longevity observed in male was 1.45 **±** 0.42 with range of 1-2 and in female 1.4 **±** 0.44 with range of 1-2 in male and female (Table-4.3).

The findings were related to Mir *et al.,*2014 who reported average longevity of adults as 1.4 ± 0.16 days in unfed condition after their emergence. The longevity of male and female extended up to 2.8 ± 0.13 and 3.6 ± 0.16 days when fed on water. When flies were provided with water and honey (1:1) they lived up to 23.6 ± 2.65 in male and 23 ± 0.17 days in female, respectively.

Table 4.3: Adult longevity (days) of the melon fruit fly, *B. cucurbitae* on various food sources

Treatments	Adult longevity (days)			
	Male		Female	
	Range	Mean ± SD	Range	Mean ± SD
T1 Water only	2-3	2.7 ± 0.40	3-4	3.4 ± 0.44
T2 Water + Honey (1:1)	12-32	22.8 ± 5.58	14-30	22.2 ± 4.81
T3 No food and water	1-2	1.45 ± 0.42	1-2	1.4 ± 0.44

*Mean of 10 observations

4.2 Bio-efficacy of insecticides against cucumber fruit fly, *B. cucurbitae*

Bio-efficacy of newer insecticides against cucumber fruit fly was undertaken during *Summer* 2020-2021. Total two sprays were taken at interval of 15 days.

4.2.1 Bio-efficacy of insecticides against cucumber fruit fly recorded at different intervals after first spray

Data of bio-efficacy of newer insecticides against cucumber fruit fly are given in Table 4.4. The data on efficacy of insecticides revealed that no infestation of fruit flies was observed on the experimental plots during vegetative phase of the crop. The infestation of cucumber fruit fly one day before application of insecticides ranged from 40.38 to 48.36 per cent. The differences among the treatments and replications were non-significant indicating uniform distribution of pest in both treatments and replications.

The observations recorded on third day after first spray indicated that the treatment spinosad 45 SC dose was found to be most effective treatment with 16.97 percent fruit infestation which was at par with emamectin benzoate 5 SG dose (18.85 %) and chlorantraniprole 18.55 SC dose (20.31 %) fruit infestation. Further it was observed that emamectin benzoate 5 SG dose (18.85%) was at par with cyantraniliprole 10 SC dose (22.84 %) and flubendiamide 480 SC dose (21.25 %). These treatment were followed by lambda cyhalothrin 5 EC dose with (23.85 %) and novaluron 10 EC dose with (24.52 %) infestation. The maximum 48.36 % fruit infestation was noticed in untreated control.

On the seventh day after spraying the minimum (14.89%) fruit infestation observed in treatment spinosad which was at par with emamectin benzoate which recorded 16.35 per cent fruit infestation. The treatment emamectin benzoate (16.35%) was found at par with chlorantraniliprole 18.45 per-cent infestation. chlorantraniliprole (18.45%) was found at par with flubendiamide (19.36%) and cyantraniliprole 20.76 per-cent infestation. These treatments were followed by lambda cyhalothrin with (21.93 %) and novaluron with (22.37) per-cent infestation. The maximum 49.71 percent fruit infestation was noticed in untreated control.

At 14 DAS minimum (18.81%) fruit infestation observed in treatment spinosad which was at par with emamectin benzoate which recorded 19.33 per cent fruit infestation. These treatments were followed by flubendiamide (22.89%), chlorantraniliprole (22.98%), lambda cyhalothrin (24.15%), cyantraniliprole (24.46%) and novaluron with (25.37) per-cent infestation. The maximum fruit infestation (49.99 %) was noticed in untreated control.

The data on cumulative per cent mean infestation revealed that the treatment spinosad was found to be most effective treatment which recorded 16.89 per cent fruit infestation and was at par with emamectin benzoate (18.18%). The treatment are followed by chlorantraniliprole (20.58%), flubendiamide (21.17%), cyantraniliprole (22.68%), lambda cyhalothrin (23.31%), and novaluron with (24.09) per-cent infestation. The maximum fruit infestation (49.46 %) was noticed in untreated control.

Table No.4.4: Bio-efficacy of different insecticides against cucumber fruit fly *B. cucurbitae* (first spray)

Per-cent fruit damage due to cucumber fruit fly *B. cucurbitae* (first spray)						
Treatment No.	**Treatment Name**	**1 DBS**	**3 DAS**	**7 DAS**	**14 DAS**	**Mean**
T_1	Emamectin benzoate 5 SG	43.51 (41.25)*	18.85 (26.43)	16.35 (23.83)	19.33 (26.06)	18.18 (25.21)
T_2	Flubendiamide 480 SC	45.09 (42.16)	21.25 (27.39)	19.36 (26.08)	22.89 (28.57)	21.17 (27.36)
T_3	Spinosad 45 SC	41.52 (40.10)	16.97 (24.31)	14.89 (22.68)	18.81 (25.68)	16.89 (24.23)
T_4	Cyantraniliprole 10 SC	41.86 (40.29)	22.84 (28.52)	20.76 (27.08)	24.46 (29.62)	22.68 (28.42)
T_5	Novaluron 10 EC	42.01 (40.37)	24.52 (29.66)	22.37 (28.21)	25.37 (30.21)	24.09 (29.37)
T_6	Lambda cyhalothrin 5 EC	42.45 (40.63)	23.85 (29.16)	21.93 (27.90)	24.15 (29.41)	23.31 (28.85)
T_7	Chlorantraniliprole 18.5 SC	40.38 (39.43)	20.31 (26.77)	18.45 (25.42)	22.98 (28.63)	20.58 (26.94)
T_8	Untreated control	48.36 (44.04)	48.68 (44.22)	49.71 (44.81)	49.99 (44.97)	49.46 (44.67)
	SE (m) ±	0.889	0.913	0.707	0.819	0.317
	C.D. at 5 %	N/A	2.79	2.16	2.50	0.971

*figures in parentheses are arc sign transformed values, NS- Non-significant, DBS: Day before spraying, DAS: Day after spraying.

4.2.2 Bio-efficacy of insecticides against cucumber fruit fly recorded at different intervals after second spray

The results on effect of second spray are presented in Table 4.5. The observations recorded on third day after second spray revealed that the per cent fruit infestation in the treatment with spinosad 45 SC was minimum (09.87%) and found significantly superior over rest of the treatments followed by emamectin benzoate 5

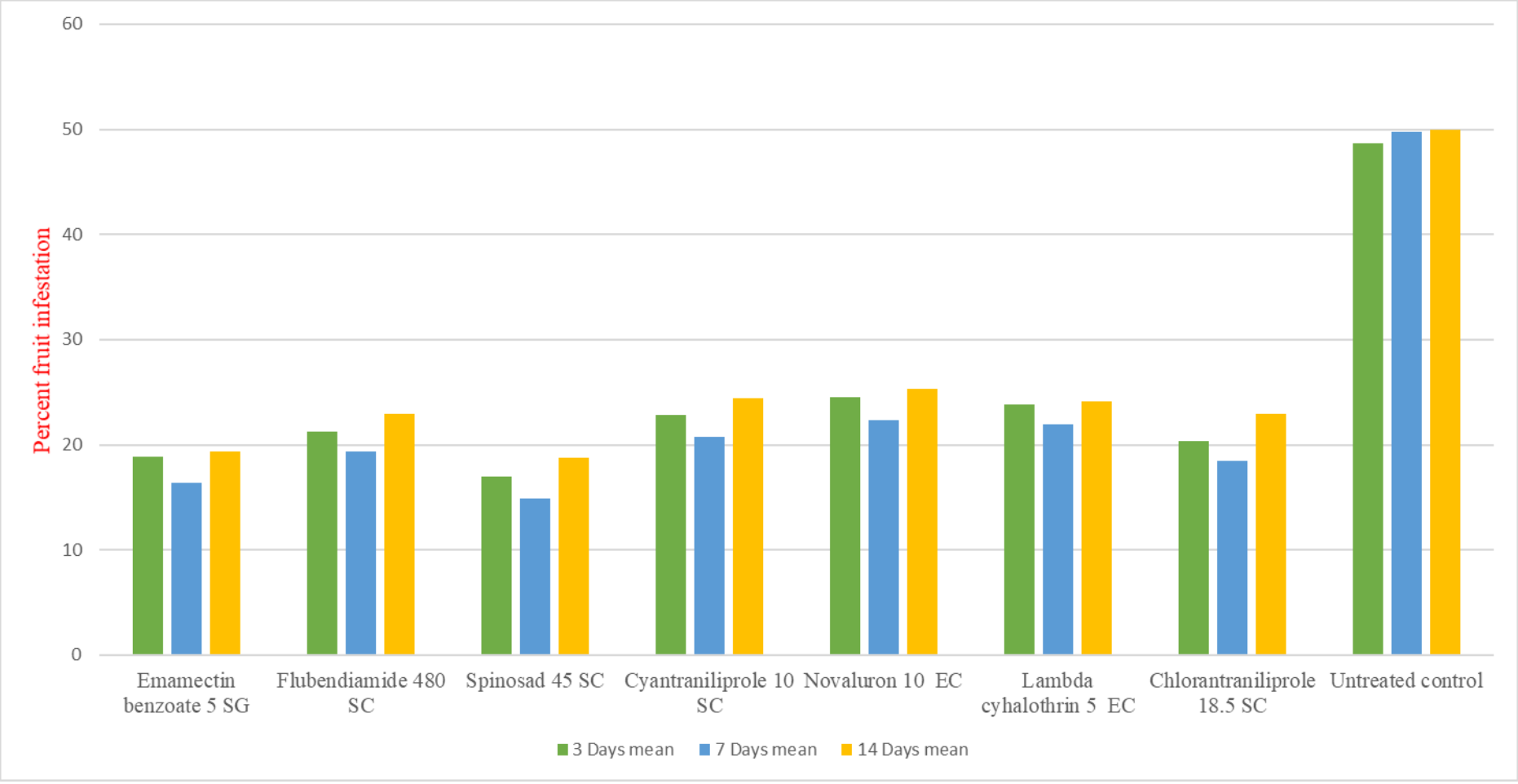

Fig.no.4.1 Bio-efficacy of different insecticides against cucumber fruit fly, *Bactrocera cucurbitae* (first spray)

SG which recorded 12.94 per -cent fruit infestation, which was at par with chlorantraniliprole 18.5 SC (14.97%). This treatment are followed by cyantraniliprole 10 SC (16.26%), flubendiamide 480 SC (16.59%), lambda cyhalothrin 5 EC (17.31%), and novaluron 10 EC with 19.09 per-cent infestation. The maximum 50.37 per -cent fruit infestation was noticed in untreated control.

On the seventh day after spraying the minimum (11.11%) fruit infestation was observed in treatment spinosad which was at par with emamectin benzoate that recorded 11.92 per- cent fruit infestation. The treatment emamectin benzoate (10.62%) was found at par with chlorantraniliprole (13.00) percent infestation. These treatment were followed by cyantraniliprole 10% S.C (14.79%) flubendiamide (15.42%), lambda cyhalothrin (17.83%), and novaluron 17.91 per-cent infestation. The maximum 47.31 per -cent fruit infestation was noticed in untreated control.

On day 14th, per- cent fruit infestation in the treatment with spinosad was minimum (11.92%) and was at par with emamectin benzoate which recorded 13.14 per cent fruit infestation. Emamectin benzoate (13.14%) was at par with chlorantraniliprole (16.51) per-cent fruit infestaion. Cyantraniliprole recorded 18.12 per-cent infestation which was at par with flubendiamide 19.09 per-cent fruit infestation. This treatment was followed by lambda cyhalothrin (24.58%), and novaluron with (26.16) per-cent infestation. The maximum (51.34) per-cent fruit infestation was noticed in untreated control.

The data on cumulative per cent mean infestation of second spray revealed that the treatment spinosad was found to be the most effective treatment which recorded 10.97 per-cent fruit infestation and was at par with emamectin benzoate (12.67%) which was at par with chlorantraniliprole (14.83%). Cyantraniliprole (16.39%) was at par with flubendiamide (17.04%). This was followed by lambda cyhalothrin (19.91%) and novaluron with 21.05 per-cent infestation. The maximum 49.89 percent fruit infestation was noticed in untreated control.

Table No. 4.5: Bio-efficacy of different insecticides against cucumber fruit fly *B. cucurbitae* (second spray)

Per-cent fruit damage on 5 plants due to cucumber fruit fly *Bactrocera cucurbitae* (second spray)					
Treatment no.	**Treatment name**	**3 DAS**	**7 DAS**	**14 DAS**	**Mean**
T1	Emamectin benzoate 5 SG	12.94 (21.05)*	11.92 (20.18)	13.14 (21.23)	12.67 (20.83)
T2	Flubendiamide 480 SC	16.59 (23.99)	15.42 (23.11)	19.09 (25.88)	17.04 (24.34)
T3	Spinosad 45 SC	9.87 (18.26)	11.11 (19.43)	11.92 (20.17)	10.97 (19.31)
T4	Cyantraniliprole 10 SC	16.26 (23.75)	14.79 (22.59)	18.12 (25.17)	16.39 (23.85)
T5	Novaluron 10 EC	19.09 (25.88)	17.91 (25.01)	26.16 (30.74)	21.05 (27.22)
T6	Lambda cyhalothrin 5 EC	17.31 (24.56)	17.83 (24.93)	24.59 (29.71)	19.91 (26.42)
T7	Chlorantraniliprole 18.5 SC	14.97 (21.92)	13.00 (21.10)	16.51 (23.94)	14.83 (22.61)
T8	Untreated control	50.37 (45.19)	47.96 (43.81)	51.34 (45.75)	49.89 (44.91)
	SE (m) ±	0.523	0.420	0.571	0.636
	C.D. at 5 %	1.60	1.28	1.23	1.94

*figures in parentheses are arc sign transformed values, NS- Non-significant, DBS: Day before spraying, DAS: Day after spraying.

4.2.3 Cumulative bio- efficacy of insecticides against cucumber fruit fly (Mean of first and second spray)

The data of cumulative efficacy of insecticides against fruit flies infesting cucumber are presented in Table 4.6. The results regarding cumulative mean of two sprays revealed that spinosad was the best treatment which recorded minimum (13.93%) mean fruit infestation and was at par with emamectin benzoate (15.43%). Emamectin benzoate (15.43%) was par with chlorantraniliprole (17.71%) and

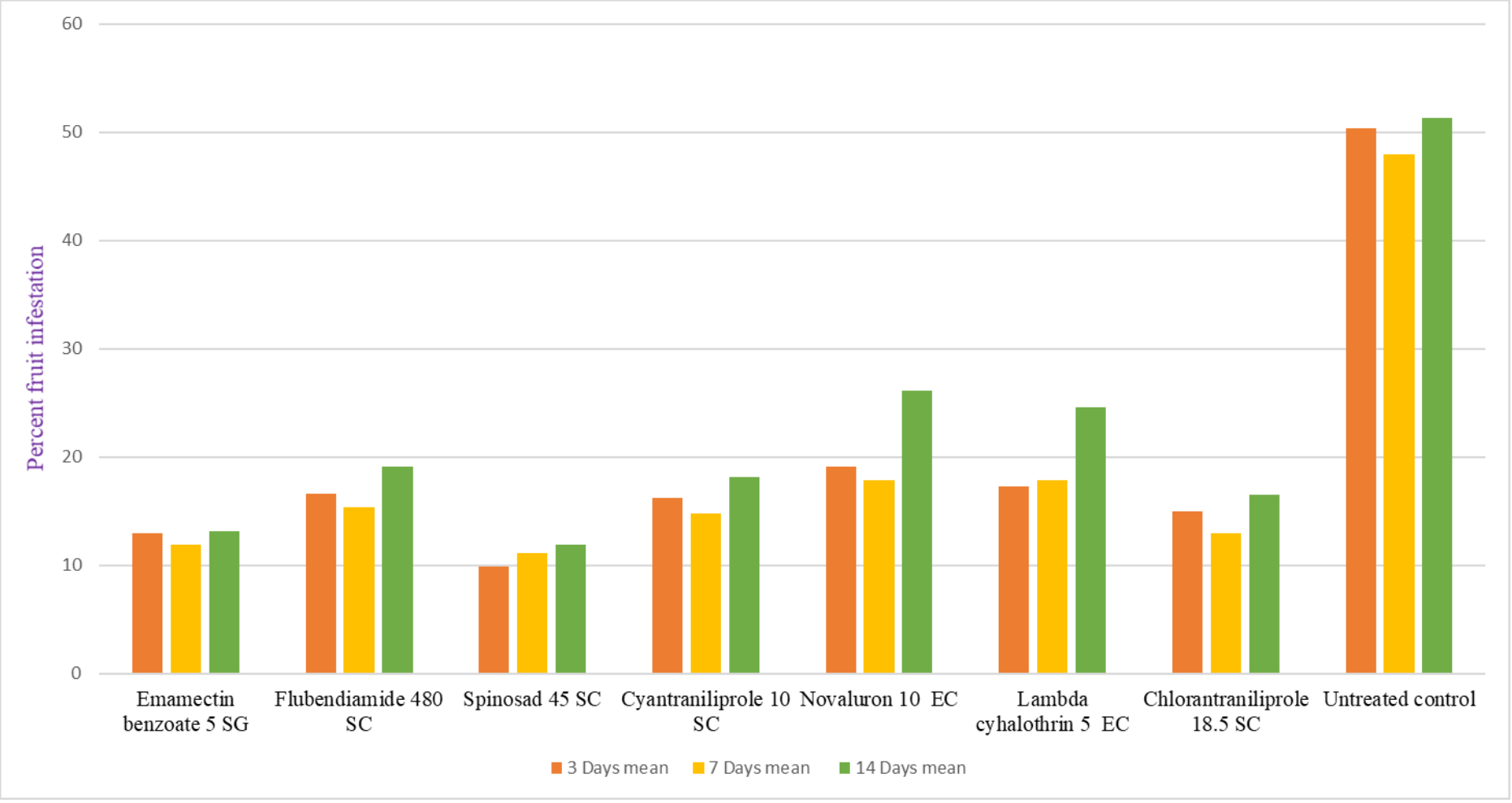

Fig.no.4.2 Bio-efficacy of different insecticides against cucumber fruit fly, *B. cucurbitae* (second spray)

flubendiamide (19.11%) mean fruit infestation. Chlorantraniliprole 18.5% SC (17.71%) was par with flubendiamide 480 % SC (19.11%) cynantranprole (19.54) and lambda cyhalothrin (21.61%) mean per-cent infestation. which was followed by novaluron 22.57. All above treatments were found to be superior over untreated control which recorded highest fruit infestation (49.68%).

The present findings are in agreement with Shinde *et al*. (2018), they recorded lowest mean fruit infestation in spinosad (11.54%) followed by emamectin benzoate which recorded 15.42 %. Srinivas *et al.* (2018) tested 9 insecticides against cucumber fruit fly, *B. cucurbitae* and recorded lowest mean fruit infestation in spinosad 45 SC in *Kharif* 2017 and *Summer* 2018 (14.92% and 17.90%). Sharma and Gupta (2019) evaluated seven insecticides against cucumber fruit fly *B. cucurbitae* and documented that emambectin benzoate was found second best treatment with 24.64 % mean fruit infestation. Sharma and Gupta (2019) evaluated 12 insecticides and bio-pesticides against cucumber fruit fly *B. cucurbitae* and recorded spinosad as second best treatment with 25.41, 23.69 and 28.45, 25.85 mean percent fruit infestation during 2014 and 2015 respectively.

Lekha and Swami (2017) evaluated different insecticides and recorded three sprays of spinosad 45 SC (200ml/ha) proved to be the best treatment with 15.92 % mean per-cent fruit infestation. Nehra *et al*. (2019) evaluated 9 insecticides against fruit fly on round gourd, spinosad 45 SC was found most effective with 5.60 per-cent fruit infestation. The next effective treatments were acephate + molasses followed by acephate and fipronil. Hirekurubar and Tatagar (2018) recorded the highest yield in spinosad 45 SC (103.75 q/ha) which was found to be par with chlorantraniliprole 18.5% SC (98.48 q/ha)

Table 4.6. Bio-efficacy of different insecticide against cucumber fruit fly, *B. cucurbitae* (per-cent fruit damage) [Cumulative mean of two sprays / 5 plants]

Treatment no.	Treatment name	Per cent fruit infested		Mean per-cent infestation
		First spray	Second spray	
T1	Emamectin benzoate 5 SG	18.18 (25.21)*	12.67 (20.83)	15.43 (23.03)
T2	Flubendiamide 480 SC	21.17 (27.36)	17.04 (24.34)	19.11 (25.87)
T3	Spinosad 45 SC	16.89 (24.23)	10.97 (19.31)	13.93 (21.79)
T4	Cyantraniliprole 10 SC	22.68 (28.42)	16.39 (23.85)	19.54 (26.15)
T5	Novaluron 10 EC	24.09 (29.37)	21.05 (27.22)	22.57 (28.34)
T6	Lambda cyhalothrin 5 EC	23.31 (28.85)	19.91 (26.42)	21.61 (27.67)
T7	Chlorantraniliprole 18.5 SC	20.58 (26.94)	14.83 (22.61)	17.71 (24.80)
T8	Untreated control	49.46 (44.67)	49.89 (44.91)	49.68 (44.79)
	SE (m) ±	0.317	0.636	0.873
	C.D. at 5 %	0.971	1.94	2.96

*figures in parentheses are arc sign transformed values.

4.3 Effect of different insecticides on yield of cucumber

The data presented in respect of yield influenced by various treatments was presented in table 4.7 revealed that all treatments were found effective in bringing the significant increase in the yield as compared to the untreated control. The treatment with Spinosad 45 SC recorded the highest yield of fruits (17.20 ton/ha). It was followed by emamectin benzoate SG (15.70 ton/ha), chlorantraniliprole 18.5 SC

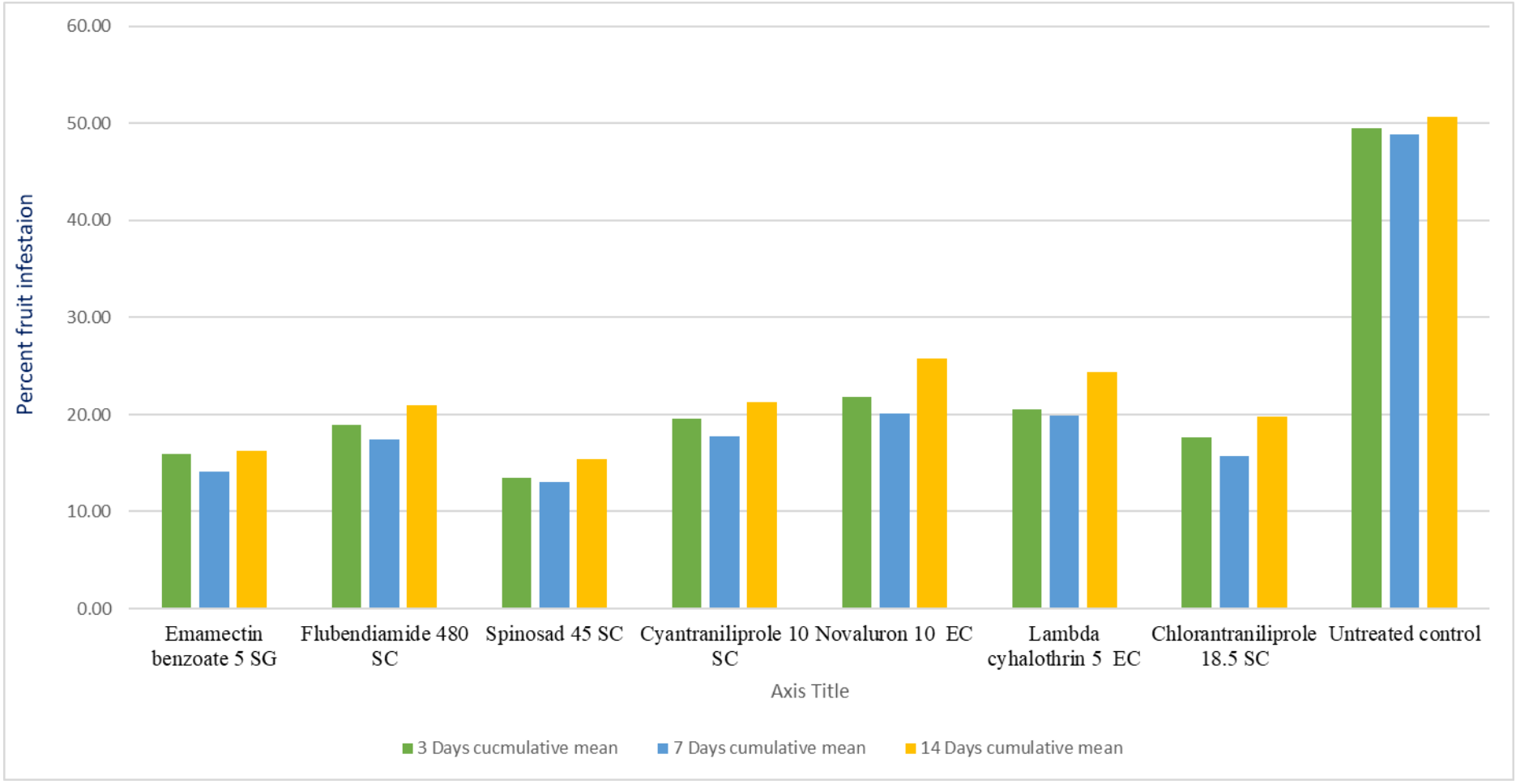

Fig.no.4.3 Cumulative bio- efficacy of insecticides against cucumber fruit fly (Mean of first and second spray)

(15.30 ton/ha), flubendiamide 480 SC (15.20 ton/ha), cyantraniliprole 10 SC (14.30 ton/ha), lambda cyhalothrin 5EC (13.70 ton/ha) and novaluron 10 EC (11.30 ton/ha). All these treatments were significantly superior over untreated control. In untreated control plot recorded lowest yield (08.10 ton/ha).

Similar reports are documented by Srinivas *et al*., (2019) who recorded about 15.63 ton/ha and 16.49 ton/ha yield in *Kharif* 2017 and *Summer* 2018 which was highest yield of cucumber by the spinosad 45 SC among 10 treatments. Sawai *et al*., (2014) recorded 17.54 ton/yield by spinosad 45 SC treatment in ridge gourd. Lekha and Swami (2017) stated that spinosad 45 SC as best treatment in yield (555 q/ha) among 7 different treatments. Nehra *et al*., (2019) recorded maximum yield in spinosad with 105.14 *ha*-1 followed by acephate 75 SP + molasses with 102.57 *ha*-1 which were at par and significantly superior to other treatments.

4.3.5 Incremental cost benefit ratio as influenced by different insecticides.

A) Gross returns (Rs/ha)

The table 4.7 represents the economics of different treatments used against cucumber fruit fly (*Bactroera cucurbitae*) *Summer* 20-21. The treatment spinosad 45 SC provided highest gross returns (Rs182000). Followed by emamectin benzoate 5 SG (Rs 152000), chlorantraniliprole 18.5 SC (Rs 144000), flubendiamide 480 SC (Rs 142000), cyantraniliprole 10 SC (Rs 124000), lambda cyhalothrin 5 EC (Rs 112000) and novaluron 10 EC (Rs 64000).

B) Net returns (Rs/ha)

The treatment Spinosad 45 SC recorded highest net returns 172900 Rs/ha followed by novaluron, emamectin benzoate 5 SG (147320), chlorantraniliprole 18.5 SC (136980), flubendiamide 480 SC (136500), cyantraniliprole 10 SC (113512), lambda cyhalothrin 5 EC (110400) and novaluron 10 EC (59000) Rs/ha.

C) ICBR

The highest benefit cost ratio was noticed in lambda cyhalothrin 5 EC (1:50.90) followed by emamectin benzoate 5 SG (1:31.47), flubendiamide 480 SC (1:24.81), chlorantraniliprole 18.5 SC (1:19.51), spinosad 45 SC (1:19), novaluron 10 EC (1:11.8) and lowest was noticed in cyantraniliprole 10 SC (1:10.82).

Table no. 4.7 Economics of different treatments for the control of fruit fly in cucumber

Treatments	Fruit yield ton/ha	Increased yield over control ton/ha	Cost of tretments Rs/ha		Total cost Rs/ha	Value of additional yield over untreated control (Rs/ha)	Net profit (Rs/ha)	ICBR	RANK
			Cost of insecticides 2 sprayings	Labour+ sprayer charges for two sprayings					
Emamectin benzoate 5 SG	15.70	7.60	3080	1600	4680	152000	147320	1:31.47	2
Flubendiamide 480 SC	15.20	7.10	3900	1600	5500	142000	136500	1:24.81	3
Spinosad 45 SC	17.20	9.10	7500	1600	9100	182000	172900	1:19	5
Cyantraniliprole 10 SC	14.30	6.20	8888	1600	10488	124000	113512	1:10.82	7
Novaluron 10 EC	11.30	3.20	3400	1600	5000	64000	59000	1:11.8	6
Lambda cyhalothrin 5 EC	13.70	5.60	600	1600	2200	112000	110400	1:50.90	1
Chlorantraniliprole 18.5 SC	15.30	7.20	5420	1600	7020	144000	136980	1:19.51	4
Untreated control	8.10	-	-	-	-	-	-	-	-

i) Emamectin benzoate 5 %SG 192 Rs/250gm
ii) Flubendiamide 480% SC 15500 Rs/lit
iii) Spinosad 45% SC 1875 Rs/lit
iv) Cyantraniliprole 10% SC 2000Rs/lit
v) Novaluron 10%EC 2265 Rs/lit
vi) Lambda cyhalothrin 5 %EC 750Rs/lit
vii) Chlorantraniliprole 18.5%SC 2710Rs/lit
viii) Marketable of cucumber Rs 20/Kg
xi) Labour charges 250/day/labour
x) Sprayer charge 200Rs/day

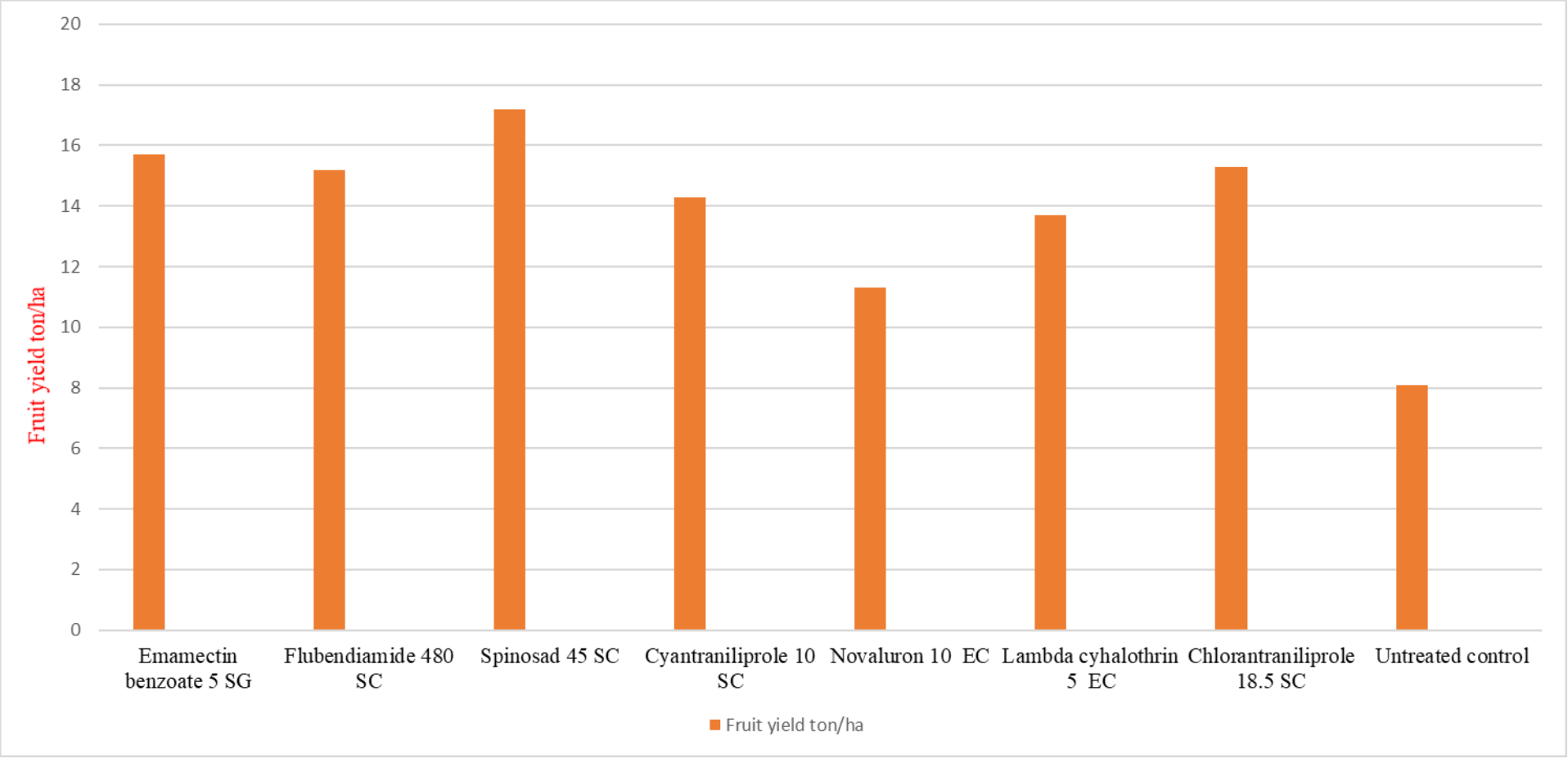

Fig.no. 4.4 Effect of different insecticides on yield of cucumber

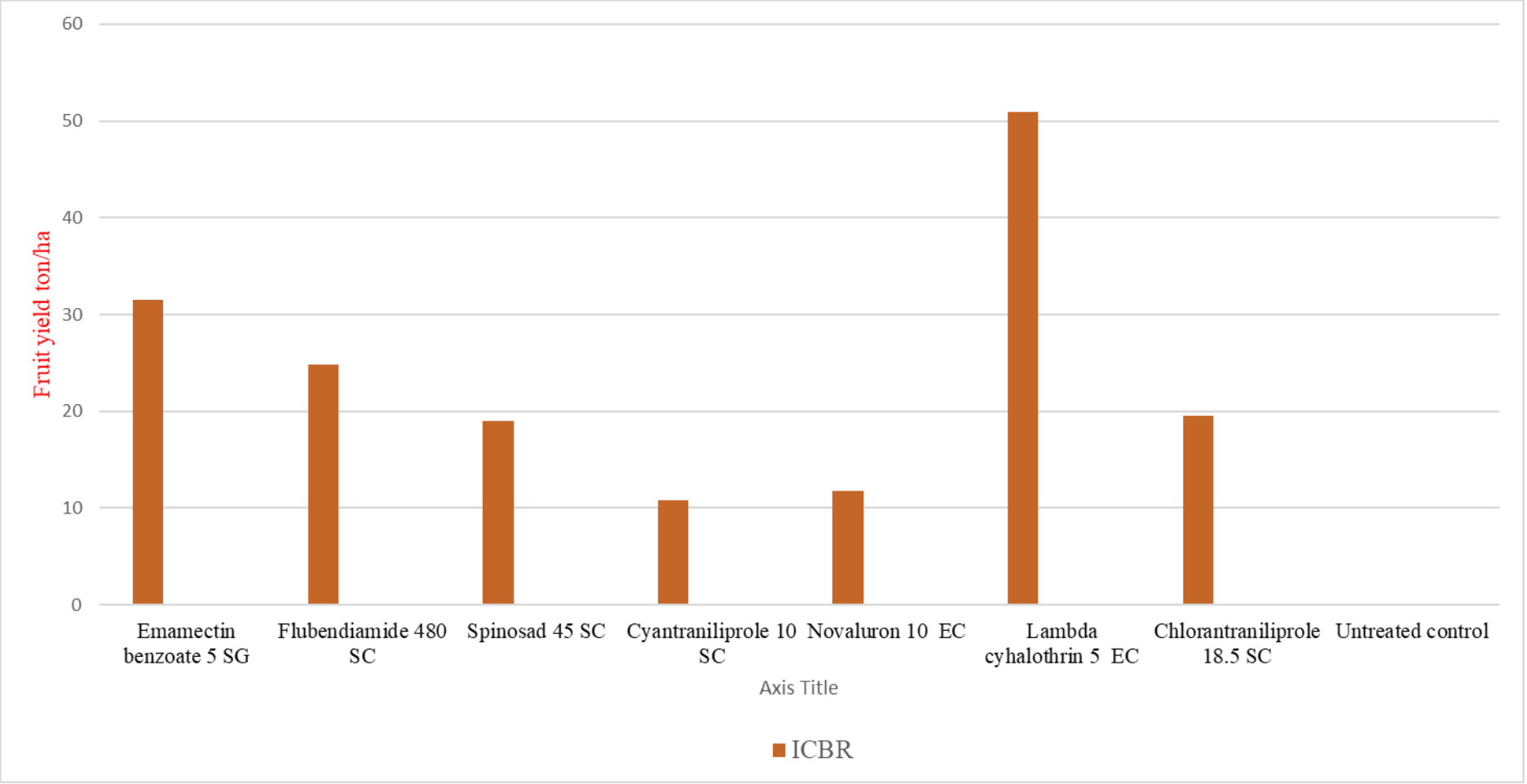

Fig.no. 4.5 Incremental cost benefit ratio (ICBR) as influenced by different insecticides on cucumber

CHAPTER – V

SUMMARY AND CONCLUSION

CHAPTER-V

SUMMARY AND CONCLUSION

The biggest threat to cucumber cultivation is the vulnerable and wide spread attack by fruit fly. *Bactrocera cucurbitae* (Coquillett), which is most serious and destructive pest of cucumber. The present experiment on biology of fruit fly, *B. cucurbitae* (Coquillett) on cucumber was carried out during *Summer* 2020-21 at Department of Agril. Entomology, VNMKV, Parbhani. Furthermore, bio-efficacy of different newer insecticides was also studied.

5.1. Biology of Fruit fly, *Bactrocera cucurbitae* (Coquillett) on cucumber

The colour of freshly laid eggs was glistering white, slightly curved, elongated and tapering at one end while rounded at other end. The average length and breadth of eggs were 1.12 mm ± 0.09 mm and 0.22 mm ± 0.04 mm. The incubation period was ranging from 12 -24 hours, with mean 17.9 ± 3.62 hours. The apodous maggots develop through three instars. The first and second instar maggot measured on an average 1.60 ± 0.24 and 6.41 ± 0.81 mm in length and 0.27 ± 0.05 and 1.18 ± 0.09 mm in breadth. Average length and breadth of full -grown maggot was 9.43 ± 0.79 and 2.06 ± 0.32 mm. The average duration of first, second and third instar maggot was 0.75 ± 0.15, 1.89 ± 0.32 and 2.43 ± 0.33 days, respectively. The total maggot period was 5.07 ± 0.42 days.

Average length and breadth of prepupa was 6.42 ± 0.15 mm and 1.98 ± 0.05 mm, with range of 6.17mm to 6.65mm in length and 1.93 mm to 2.1mm in breadth respectively. The average length and breadth of pupae were 5.65 mm ± 0.14 mm and 2.43 mm ± 0.11 mm, with range of 5.41 mm to 5.86 mm and 2.27 mm to 2.63 mm, respectively. The prepupal period ranged between 0.5 to 1 day whereas, pupal period ranged between 8-9 days. The pre-oviposition, oviposition and post-oviposition period ranged between 10 to 15 days, 2 to 4 days and 1 to 3 days with average of 12.3 ± 1.55, 2.65 ± 0.72 and 2.05 ± 0.66 days respectively. The average length and breadth (with expanded wings) of male was 8.54 mm ± 0.13 mm and 11.43 mm ± 0.95 mm, whereas, the female measured on an average 9.82 mm ± 0.15 mm in length and 15.82 mm ± 0.63 mm in breadth (with expanded wings).

The period from egg to death of adult male ranged between 27-43 days with mean of 34.6 ± 4.29 days, whereas female ranged between 30-46 days with average of 38.35 ± 4.77 days. The copulation lasted for a minimum of 2 hours to maximum of 4 hours with mean of 3.3 ± 0.78. The number of eggs laid by female ranged from 53-87 with mean of 71.9 ± 11.41. hatching percentage ranged between 81-86 with mean of 83.3 ± 1.68. Sex Ratio (Male:Female) ranged between 0.90 to 1.20 with average of 1.07 ± 0.09. When adult male and female fed on water only mean longevity observed was 2.7 ± 0.40 and 3.4 ± 0.44. When fed on water and honey (1:1) was 22.8 ± 5.58 in male and 22.2 ± 4.81 in female. When no food or water was given longevity observed in male was 1.45 ± 0.42 and in female 1.4 ± 0.44.

5.2 Bio-efficacy of insecticides against cucumber fruit fly, *B. cucurbitae*

The results regarding cumulative mean of two sprays revealed that spinosad was the best treatment which recorded minimum (13.93%) mean fruit infestation and was at par with emamectin benzoate (15.43%). Emamectin benzoate (15.43%) was par with chlorantraniliprole (17.71%) and flubendiamide (19.11%) mean fruit infestation. Chlorantraniliprole 18.5% SC (17.71%) was par with flubendiamide 480 % SC (19.11%) cynantranprole (19.54) and lambda cyhalothrin (21.61%) mean per-cent infestation. This was followed by novaluron (22.57%) mean per-cent infestation. Untreated control recorded highest fruit infestation (49.68%).

5.3 Effect of different insecticides on yield of cucumber

All treatments were found effective in bringing the significant increase in the yield as compared to the untreated control. The treatment with Spinosad recorded the highest yield of fruit (17.20ton/ha), followed by emamectin benzoate (15.70 ton/ha) and Chlorantraniliprole (15.30 ton/ha). Lowest yield was recorded in flubendiamide (15.20 ton/ha), cyantraniliprole (14.30 ton/ha), lambda cyhalothrin (13.70 ton/ha) and novaluron (11.30 ton/ha). In untreated control plot lowest yield i.e. (08.10 ton/ha) was recorded.

5.4 Incremental cost benefit ratio as influenced by different insecticides.

The highest benefit cost ratio was noticed in lambda cyhalothrin 5 EC (1:50.90) followed by emamectin benzoate 5 SG (1:31.47) and flubendiamide 480

SC (1:24.81). Lowest ICBR was recorded in chlorantraniliprole 18.5 SC (1:19.51), spinosad 45 SC (1:19), novaluron 10 EC (1:11.8) and cyantraniliprole 10 SC (1:10.82).

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