

**Studies on Biology and Management of Melon fruit fly,  
*Bactrocera cucurbitae* (Coquillett) on Cucumber**

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(MSA/2021/1427)



**Division of Entomology  
Faculty of Agriculture  
Sher-e-Kashmir University of Agricultural Sciences and  
Technology of Kashmir  
2023**

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**Thesis**  
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**in partial fulfillment of requirements for the award of the degree**  
**of**  
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**DEDICATED TO**

**MY PARENTS, ADVISOR, BROTHERS & FRIENDS**

**Sher-e-Kashmir**  
**University of Agricultural Sciences and Technology of Kashmir**  
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**193201**

**Certificate – I**

This is to certify that the thesis entitled “**Studies on Biology and Management of Melon fruit fly, *Bactrocera cucurbitae* (Coquillett) on Cucumber**” submitted in partial fulfillment of the requirements for the award of the degree of **Master of Science in Agriculture (Entomology)**, to the **Faculty of Agriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir** is a record of bonafide research work carried out by **Miss Rabia Aziz Bhat (Regd. No. MSA/2021/1427)** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

It is further certified that information received during the course of investigation has duly been acknowledged.

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**ABSTRACT**

The present studies entitled “Studies on Biology and Management of Melon fruit fly, *Bactrocera cucurbitae* (Coquillett) on Cucumber” were carried out at Research laboratory and Research farm of Division of Entomology, FoA Wadura, during the year 2022. Studies on biology of melon fruit fly, *B. cucurbitae* (Coquillett) revealed that the average duration of incubation, maggot, prepupal and pupal period varied between  $2.01 \pm 0.67$ ,  $5.45 \pm 1.28$ ,  $1.13 \pm 0.60$  and  $7.79 \pm 1.45$  days, respectively. Pre-oviposition and oviposition period ranged between  $12.3 \pm 2.36$  and  $17.57 \pm 5.50$  days respectively, during July to August. The fecundity varied between 52-90 eggs, hatching percentage was 83-88%, while as sex ratio (Male: Female) in *B. cucurbitae* was recorded as 0.88-1.30. Morphometric measurements of life stages of *B. cucurbitae* revealed that freshly laid eggs were glistening white, slightly curved, elongated and tapering at one end, while rounded at the other end. The mean length and breadth of the egg was  $1.11 \pm 0.18$  and  $0.27 \pm 0.04$  mm. The first and second instar maggots measured on an average  $2.30 \pm 0.98$  and  $5.62 \pm 1.24$  mm in length and  $0.35 \pm 0.10$  and  $1.25 \pm 0.16$  mm in breadth. The full grown maggot was mobile and measured  $8.95 \pm 0.95$  and  $2.08 \pm 0.46$  mm in length and breadth. The melon fly puparium was found to be barrel shaped, eleven segmented and measured on an average  $5.09 \pm 0.44$  and  $2.04 \pm 0.26$  mm in length and breadth. The average length and breadth (with expanded wings) of male was  $7.48 \pm 0.74$  and  $12.39 \pm 1.56$  mm, whereas, the female measured on an average  $9.22 \pm 0.75$  and  $15.37 \pm 1.08$  mm in length and breadth (with expanded wings). Among the various protein baits tested from July to October during the year 2022, protein hydrolysate, soya powder and molasses, were good sources of protein and were promising in attracting adult melon fruit

flies. T<sub>4</sub> (Protein hydrolysate 10 ml) + Cue lure (1 ml) + Dimethoate 30 EC (1 ml) proved to be the most efficient and the mean trap was 21.55 flies/trap, followed by T<sub>1</sub> (Soya powder (10g) + Cue lure (1ml) + Dimethoate 30 EC (1ml) *i.e.*, 17.11 flies/trap and least number of insects were trapped in T<sub>5</sub> (Control) *i.e.*, 7.59 flies/trap. Yellow and green sticky traps attracted significantly high number of *B. cucurbitae* *i.e.*, 12.27 and 10.06 flies/trap, while as blue and white sticky traps were least effective, attracting considerably lower number of melon fruit flies *i.e.* 4.45 and 5.65 flies/trap. Yellow and green coloured spherical traps attracted significantly high number of *B. cucurbitae* *i.e.*, 13.16 and 10.78 flies/trap and the least number were captured by orange trap *i.e.*, 6.37 flies/trap. Among the transparent manual traps, the traps that were hung at 2m height captured significantly higher number of *B. cucurbitae* followed by those hung at 2.5m (10.74 flies/trap) and 1.5m (8.85 flies/trap) and the least were captured by the trap hung at 1m (3.49 flies/trap).

**Key words:** Biology; Morphometrics; Diptera; Tephritidae; Management; Melon fruit fly.

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*Rabia Aziz Bhat*

*Place: Wadura, Sopore*

*Dated:*

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## Chapter-1

### INTRODUCTION

Cucumber (*Cucumis sativus* L.) belongs to Cucumis genus in Cucurbitaceae family and is an economically important vegetable crop. It is a summer vegetable crop and the plant has a trailing or climbing habit. Fruit can be eaten raw, cooked or used in making pickles. Cucumber has versatile uses in culinary, therapeutic and cosmetic purposes (Mukherjee *et al.*, 2013; Muruganantham *et al.*, 2016). Cucumber contains a lot of nutrients and has a crunchy texture with a unique flavour, so it is an essential vegetable. It is used in a number of dishes, and is also used for making salad, smoothie and soup. Cucumber is rich in superior hydration and phytochemicals, which have diverse health benefits including weight loss, anti-inflammation, remedy for multiple diseases of eczema, constipation, hypertension, atherosclerosis, cancer, *etc.* (Oboh *et al.*, 2017). Recent studies have found the presence of kaempferol in cucumber which is an important antidiabetic agent (Ibitoye *et al.*, 2018). Furthermore, cucumber is popularly used for natural beautification and for skin treatments (Fiume *et al.*, 2014). At present, cucumber is the fourth most widely cultivated vegetable after tomato, cabbage and onion (Jamir and Sharma, 2014).

Cucumber is widely cultivated in temperate and tropical regions throughout the world. China is the world's largest producer of cucumber with production of 91.258 lakh tonnes, accounting for 79.75% of the world's cucumber production (Anonymous, 2020). World acreage under cucumber is about 2.26 million hectares with a total annual production of 91.2 million tonnes and productivity of 40.4 tonnes per hectare (Anonymous, 2020).

In India it is cultivated in an area of 82 thousand hectares with an annual production of 1.26 million tonnes with a productivity of 15.27 tonnes per hectare (Anonymous, 2018). In Jammu and Kashmir, the area and

production under this crop is 1.28 thousand hectares and 28.59 thousand metric tonnes, respectively (Anonymous, 2018).

There are a number of insect pests of cucumber like aphid (*Aphis gossypii*), cucumber beetle (*Diabrotica undecimpunctata*), vine borer (*Melittia cucurbitae*), squash bug (*Anasa tristis*) and melon fruit fly (*Bactrocera cucurbitae*). Out of which melon fruit fly is an important major pest infesting cucumber as well as other cucurbitaceous crops like fruits of bitter gourd (*Momordica charantia*), muskmelon (*Cucumis melo*), snap melon (*Cucumis melo* var. *momordica*) and snake gourd (*Trichosanthes anguina* and *T. cucumeria*). Melon fruit fly, *B. cucurbitae* is known to damage more than 81 plant species but plants belonging to the family Cucurbitaceae are preferred most (Allwood *et al.*, 1999).

Melon flies are the most serious pests because of their polyphagous nature and cause huge economic losses varying from 30-100% depending on the susceptibility of the crop and season (Dhillon *et al.*, 2005). Melon fruit fly causes 31.27% damage on bitter gourd and 28.55% damage on watermelon in India (Singh *et al.*, 2000).

*Bactrocera cucurbitae* prefers young, soft-skinned ovaries even before anthesis (Jakhar *et al.*, 2020). Female fruit fly punctures the skin of tender fruits or sometimes young leaves or the stem of host plant with the help of its ovipositor and deposits its eggs inside (Chaudhary and Patel, 2007). Fruit sap oozes out at the site of puncture which transforms into a resinous brown deposit (Sohel *et al.*, 2018). As the eggs hatch inside the fruit, the maggots make tunnels and feed on the pulp inside causing direct damage to the fruit. Indirect damage is caused by the pathogens and bacteria which hasten rotting of fruits.

Management practices such as spray of neem oil, para-pheromone traps, bagging of fruits and food lures and use of other chemical insecticides have been in use since a long time for managing cucurbit fruit fly (Subedi *et al.*, 2021). In general, the management practices for fruit flies are the usage of food lures, parapheromone traps, fruit bagging and spraying of chemical insecticides

(Sapkota *et al.*, 2010). Farmers have long been using chemical pesticides, pheromone traps and field sanitation to manage cucurbit fruit fly effectively (Gc and Mandal, 2000). Some of the management practices either fail to control the pest or are hazardous to non-target animals and environment (Manjunathan, 1997; Singh and Singh, 1998; Neupane, 2000; Dhillon *et al.*, 2005)

Moreover, due to repeated use of chemical insecticides, the fruit fly has gained resistance and resurgence against new insecticides (Wang *et al.*, 2015) and in this way the cost of production is also increased (Nasiruddin *et al.*, 2004). Therefore, pest management tactics like trapping methods are an important alternative to the use of synthetic chemical insecticides (El-Wakeil and Nabil, 2013).

Successful and economic production of cucurbitaceous crops in J&K needs efficient knowledge for effective management of cucurbit fruit fly. Biological studies of the pest like oviposition, fecundity, sex ratio, adult longevity and incubation period *etc.* are important to devise the effective and efficient management strategy.

Keeping in view the importance of the crop and the damage caused by melon fruit fly to cucumber, the present investigations were initiated to study the biology of the pest and its management strategies. Based on above facts, the experiment has been designed with following specific objectives:

1. To study the biology of melon fruit fly under laboratory conditions.
2. To develop management strategy against *Bactrocera cucurbitae* under field conditions.

## Chapter-2

### REVIEW OF LITERATURE

The literature related to the study of the biology and management strategies against melon fruit fly put forth by various workers in India and abroad are reviewed as under:

#### **2.1 Biology of melon fruit fly, *Bactrocera cucurbitae* on cucumber under laboratory conditions.**

##### **2.1.1 Egg structure and size**

Narayanan and Batra (1960) observed that *B. cucurbitae* eggs were creamy white, banana shaped and were about 1.3 mm in length. The anterior end of eggs appeared pointed while as posterior end was more rounded.

Weems and Heppner (2001) reported that the eggs of *B. cucurbitae* are pure white in colour, about 2 mm long, elliptical, nearly flat on the ventral surface, more convex on the dorsal side and often are somewhat curved. However, Kumar and Agarwal (2004) reported that the eggs of *B. cucurbitae* were slightly curved on one side, whereas other side was straight and elongated; posterior end rounded while anterior end was pointed.

Shivayya *et al.* (2007) found that freshly laid eggs of *B. cucurbitae* were cylindrical, glistening white, slightly curved and more convex on the dorsal side. The length and breadth was measured as 1.5 and 0.34 mm, respectively.

Waseem *et al.* (2012) reported that the freshly laid eggs of *B. cucurbitae* 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  $1.03 \pm 0.16$  mm and breadth ranged from 0.16 to 0.30 mm with a mean of  $0.23 \pm 0.04$  mm.

Laskar (2013) studied the biology and biometrics of *B. cucurbitae* on bottle gourd and pumpkin and concluded that the eggs were white, curved slightly and tapering at one end. Morphometric observations revealed that the length of egg varied from 1.22-1.36 mm and breadth from 0.18-0.32 mm.

Mir *et al.* (2014) reported that average length and breadth of eggs of *B. cucurbitae* was  $1.13\pm 0.14$  mm and  $0.28\pm 0.05$  mm when reared on cucumber.

Desai *et al.* (2018) found mean length and breadth of eggs of *B. cucurbitae* varied from  $1.26\pm 0.03$  mm and  $0.26\pm 0.02$  mm, respectively on sponge gourd.

Sohrab *et al.* (2018) reported that eggs of *B. cucurbitae* were shiny white, slightly curved, length 1.3mm, elongated, tapering at one end and rounded on the other end.

Khan and Hugar (2019) reported that the freshly laid eggs of *B. cucurbitae* were shiny, translucent and whitish in colour, cylindrical in shape, slightly curved and narrow at one end.

Gaddanakeri and Rolania (2020) reported that freshly laid eggs of *B. cucurbitae* were pure white in colour, elliptical, nearly flat on the ventral surface and slightly curved on other side. Morphometric studies revealed that the length and breadth of egg varied from 1.12-1.34 mm and 0.16-0.28 mm, respectively.

### **2.1.2 Incubation period**

Vargas *et al.* (1984) reported an incubation period of 1-9 days in melon fruit fly eggs, that varies depending upon the temperature and relative humidity, which was almost similar to the findings of Vishva (2005).

Shivayya *et al.* (2007) observed 1.08-1.5 days of incubation period in melon fruit fly eggs.

Manzar and Srivastava (2009) found that the mean incubation period, temperature and relative humidity of *B. cucurbitae* varied from ( $1.7\pm 0.12$  days,  $31.9-32.2^{\circ}\text{C}$  and  $56.7-62.8\%$ ) in 2002 and ( $1.4\pm 0.16$  days,  $27.3-30.8^{\circ}\text{C}$  and  $60.6-81.2\%$ ) in 2003, respectively.

Amin *et al.* (2011) reported that the incubation period of melon fruit fly eggs varied from 18.3-25.0 hours.

Lanjar *et al.* (2013) found that the incubation period of melon fruit fly was  $2.29 \pm 0.18$  days.

Laskar (2013) studied the incubation period of *B. cucurbitae* on two different hosts *i.e.*, pumpkin and bitter gourd. Incubation period was recorded higher in pumpkin (1.5-2.0 days) than in bitter gourd (1.50-2.25 days).

Mir *et al.* (2014) reported incubation period of *B. cucurbitae* as 12-24 hours with a mean of  $16.8 \pm 6.19$  hours.

Patel and Patel (2018) conducted a research to study the comparative biology of *B. cucurbitae* on different cucurbitaceous crops *i.e.*, bitter gourd, bottle gourd and watermelon. They concluded that the mean incubation period of fruit fly on the three was  $1.28 \pm 0.458$ ,  $1.32 \pm 0.476$  and  $1.36 \pm 0.70$  days, respectively.

Sohrab *et al.* (2018) found that incubation period of *B. cucurbitae* varied from  $1.25 \pm 0.25$  days.

Khan and Hugar (2019) reported the mean incubation period of melon fruit fly as  $1.9 \pm 0.27$  days.

Akter and Sohel (2020) observed that in *Bactrocera cucurbitae*, the mean incubation period was  $1.69 \pm 0.28$  days.

### **2.1.3 Maggot structure and size**

Laskar (2013) reported that the maggots of *B. cucurbitae* were pointed anteriorly and blunt posteriorly. The length of maggots when reared on bitter gourd ranged from 8.9-11.5 mm (mean value  $10.28 \pm 0.99$  mm) and the breadth ranged from 1.59-2.25 mm.

Akter and Sohel (2020) calculated the dimensions of different stages of *B. cucurbitae*. The length of 1<sup>st</sup>, 2<sup>nd</sup> and 3<sup>rd</sup> instars were recorded  $1.1 \pm 0.9$  mm,  $3.03 \pm 0.95$  mm and  $6.42 \pm 0.90$  mm, respectively, and the width of the three instars were  $0.22 \pm 0.11$ ,  $1.12 \pm 0.01$ ,  $2.13 \pm 0.20$  mm, respectively.

#### **2.1.3.1 First instar larva**

Mir *et al.* (2014) reported that 1<sup>st</sup> instar maggot of *B. cucurbitae* was whitish, translucent and measured  $1.49 \pm 0.28$  mm in length and  $0.31 \pm 0.07$  mm in breadth.

Sohrab *et al.* (2018) reported that the first instar maggot of *B. cucurbitae* was white in colour, translucent and it took 15-24 hrs time with a mean of  $0.81 \pm 0.19$  days to change into 2<sup>nd</sup> instar.

Gaddanakeri and Rolania (2020) reported that 1<sup>st</sup> instar maggots of *B. cucurbitae* were transparent, elongated with pointed head consisting of small mandibular hook. Morphometric observations revealed that length and breadth of 1<sup>st</sup> instar larvae was 1.16-1.84 mm and 0.20-0.36 mm, respectively.

### **2.1.3.2 Second instar larva**

Mir *et al.* (2014) reported that 1<sup>st</sup> instar maggots of *B. cucurbitae* were creamy white in colour, ellipsoidal in shape and measured  $6.40 \pm 0.86$  mm in length and  $1.21 \pm 0.09$  mm in breadth.

Sohrab *et al.* (2018) reported that the 2<sup>nd</sup> instar larvae of *B. cucurbitae* were larger in size than the 1<sup>st</sup> instar larvae and were elongate, translucent, and ellipsoidal in shape and creamy white in colour. They also reported that the 2<sup>nd</sup> instar maggots took an average time of  $1.5 \pm 0.5$  days to complete this stage and go to next instar.

Gaddanakeri and Rolania (2020) reported that the 2<sup>nd</sup> instar maggots of *B. cucurbitae* were creamy white in colour with a translucent body. The length and breadth in 2<sup>nd</sup> instar ranged from 4.90-7.15 mm and 1.06-1.32 mm, respectively.

### **2.1.3.3 Third instar larva**

Manzar and Srivastava (2009) reported that the cuticle of third instar maggots of *B. cucurbitae* was very firm, yellowish to opaque in colour than the first and second instar maggots, with peculiar jumping habit and exhibited twelve body segments.

Mir *et al.* (2014) reported that the 3<sup>rd</sup> instar maggots of *B. cucurbitae* had a habit of curving themselves and leaping into air upto a distance of 6-8 inches and this way displaced themselves from the fruit to the site of pupation. The 3<sup>rd</sup> instar maggots measured  $9.62 \pm 0.87$  mm in length and  $2.05 \pm 0.32$  mm in breadth.

Sohrab *et al.* (2018) reported that the full grown 3<sup>rd</sup> instar larvae of *B. cucurbitae* had a pointed head with well developed mandibular hooks. They also reported

that the 3<sup>rd</sup> instar larvae had a peculiar habit of curving itself and springing into air to a lateral distance of 15-20 cm by sudden relaxation of certain muscles. In this way the third instar maggots displaced themselves from the fruit to the sight of pupation. The 3<sup>rd</sup> instars took an average time of  $3.0 \pm 0.5$  days to complete this stage.

Gaddanakeri and Rolania (2020) reported that the 3<sup>rd</sup> instar maggots of *B. cucurbitae* were more yellowish and more opaque body compared to 1<sup>st</sup> and 2<sup>nd</sup> instar maggots. The length and breadth of 3<sup>rd</sup> instar maggots ranged from 8.25-10.75 mm and 1.75-2.35 mm, respectively.

#### **2.1.3.4 Maggot period**

Shivayya *et al.* (2007) reported that the maggot period of *B. cucurbitae* were 7.50, 4.50 and 5.50 days during the month of December-January, March-April and August- September, respectively.

Ullah *et al.* (2008) reared cucurbit fruit fly on five different hosts *i.e.*, squash, bottle gourd, sweet gourd, bitter gourd and snake gourd. The highest larval duration was recorded on bitter gourd ( $8.67 \pm 0.58$  days), followed by snake gourd ( $8.33 \pm 0.66$  days) and lowest on squash ( $7 \pm 0.58$  days).

Patel and Patel (2018) conducted a research to study the comparative biology of *B. cucurbitae* reared on different cucurbitaceous crops *i.e.*, bitter gourd, bottle gourd and watermelon. They concluded that the total larval period on the three was  $6.08 \pm 0.493$ ,  $8.12 \pm 0.332$  and  $8.08 \pm 0.812$  days, respectively.

Sohrab *et al.* (2018) reported that the developmental period of 1<sup>st</sup>, 2<sup>nd</sup> and 3<sup>rd</sup> instars of *B. cucurbitae* were 0.62-1.0, 1.0-2.0 and 2.5-3.5 days, respectively and the total maggot period was 4.12- 6.50 days.

Khan and Hugar (2019) reported that the total maggot period of *B. cucurbitae* lasted for  $12.08 \pm 0.98$  days.

Akter and Sohel (2020) reported that 1<sup>st</sup> instar duration was  $1.72 \pm 0.33$  days, 2<sup>nd</sup> instar duration  $1.41 \pm 0.31$  days and 3<sup>rd</sup> instar duration of  $2.31 \pm 0.51$  days in case of *B. cucurbitae*.

#### **2.1.4 Prepupa and Pupa**

Agarwal *et al.* (1987) stated that *B. cucurbitae* pupa was barrel shaped, light brown or pale coloured and measured 5-8 mm long and 2.00 mm broad.

Weems and Heppner (2001) found puparium length 5 to 6 mm and opined that colour varied from dull red or brownish yellow to dull white, depending upon the host.

Kumar and Agarwal (2004) reported that *B. cucurbitae* puparia was usually pale-yellow coloured and measured 4.8-6.0 mm in length.

Shivayya *et al.* (2007) reported that the puparium of *B. cucurbitae* was cylindrical or elliptical shaped, 4 to 6 mm long and 1.7 to 2.5 mm wide. However, brownish yellow coloured with 11 distinct segments, the first segment of puparia was composed of first and second maggot segments.

Manzar and Srivastava (2009) reported the freshly formed pupa of *B. cucurbitae* was cream coloured which turned dark yellow within 4-5 hours and later changed from brownish to ochraceous. The pupae were barrel shaped with eleven distinct segments and the last segment was relatively more prominent.

Laskar (2013) found that the 3<sup>rd</sup> instar maggots of *B. cucurbitae* leave the infested fruits and become sluggish before pupation, stop feeding, contract longitudinally and assuming pre-pupal stage. He concluded that length of pre-pupa varied from 6.2-7.5mm (mean  $\pm$  SD = 6.89  $\pm$  0.46 mm) in bitter gourd. He also found that the pupae were segmented, barrel shaped and yellowish white in colour, later on the colour changed into light brown to brownish grey. The length and breadth of pupa were 5.3-6.5 mm and 2.1-2.6 mm in bitter gourd, respectively.

#### **2.1.5 Prepupal and Pupal Period**

Shivarkar and Dumbre (1985) found that the mean duration of pupal period of *B. cucurbitae* was 6.55 days. Khan *et al.* (1993) recorded a pupal duration of 6.5-21.8 days in case of *B. cucurbitae*.

Gupta and Verma (1995) reported that the pupal duration of *Dacus cucurbitae* was about 7.7-9.4 days on bitter gourd, cucumber and sponge gourd.

Hollingsworth *et al.* (1997) reported that the pupal period of melon fruit fly varied from 7-13 days depending on the temperature and host.

Manzar and Srivastava (2009) found that the duration of pupal period of *B. cucurbitae* was  $7.3 \pm 0.23$  days while as, Shivayya *et al.*, 2007 found the pupal period of 7-10.75 days.

Ullah *et al.* (2008) reared cucurbit fruit fly on five different hosts *i.e.*, squash, bottle gourd, sweet gourd, bitter gourd and snake gourd. The mean pupal period was shorter on bitter gourd ( $5.33 \pm 0.12$  days) and highest on squash ( $8.33 \pm 2.50$  days).

Laskar (2013) found that the duration of pupal stage of *B. cucurbitae* varied from 6-8 days on bitter gourd.

Patel and Patel (2018) conducted a research to study the comparative biology of *B. cucurbitae* reared on different cucurbitaceous crops *i.e.*, bitter gourd, bottle gourd and watermelon and concluded that the pre pupal and pupal period of fruit fly were  $1.08 \pm 0.277$  and  $5.88 \pm 0.6$  days on bitter gourd,  $1.12 \pm 0.332$ ,  $7.16 \pm 0.374$  days on bottle gourd and  $1.08 \pm 0.277$ ,  $9.4 \pm 0.645$  days on watermelon, respectively.

Sohrab *et al.* (2018) reported that mean of pre-pupal and pupal period of cucurbit fruit fly was  $0.75 \pm 0.25$  days and  $8.4 \pm 0.51$  days respectively.

Akter and Sohel (2020) reported that pre-pupal and pupal period was  $0.74 \pm 0.28$  days and  $9.2 \pm 0.78$  days. The total developmental period was  $36 \pm 1.69$  days.

#### **2.1.6 Adult male and female**

Laskar (2013) reported that the abdomen of adult male fruit fly was blunt and were smaller in size than females. The length, breadth (wing expanse) and weight of adult male was 5.55-7.20 mm, 10.10-12.65 mm and  $12.82 \pm 0.79$  mg, respectively when reared on bitter gourd. The adult female had a tapering ovipositor and comparatively larger than male. Length, breadth and weight of female fruit fly were found to be 7.45-9.5 mm, 12.2-16.5 mm and 12.9-15 mg respectively, when reared on bottle gourd.

Mir *et al.* (2014) reported that the adult female of *B. cucurbitae* was larger in size than the male and were easily distinguishable by having pointed end of abdomen. The length and breadth of male with expanded wings was  $8.74 \pm 0.32$  mm and  $11.46 \pm 1.16$  mm, respectively while as, for female the dimension was  $9.94 \pm 0.20$  mm and  $15.92 \pm 0.74$  mm, respectively.

Akter and Sohel (2020) reported that adult males of *B. cucurbitae* had blunt abdomen as the ovipositor was absent and were smaller in size than females while as, females had pointed or tapering abdomen due to the presence of ovipositor. When reared on bottle gourd the length and breadth of male fruit fly was  $6.61 \pm 0.59$  mm and  $10.97 \pm 0.43$  mm, respectively, while as, the length and breadth of female fruit fly was  $8.28 \pm 0.52$  mm and  $13.02 \pm 1.28$  mm, respectively.

#### **2.1.7 Preoviposition, Oviposition and Post oviposition period**

Ullah *et al.* (2008) reported highest oviposition period of fruit flies reared on squash ( $35.33 \pm 2.08$  days) followed by sweet gourd ( $35 \pm 1$  days).

Mir *et al.* (2014) while rearing melon fruit flies on cucumber found that the pre-oviposition period of  $12.4 \pm 2.36$  days and oviposition period of  $18.2 \pm 5.6$  days.

Sohrab *et al.* (2018) reported the pre-oviposition and oviposition period of *B. cucurbitae* to be  $13.5 \pm 1.5$  days and  $18.0 \pm 6.0$  days, respectively.

#### **2.1.8 Fecundity and Hatching**

Ullah *et al.* (2008) reported that squash was found to be most suitable host for egg laying of *B. cucurbitae* ( $237.53 \pm 17.87$ ), followed by sweet gourd with the fecundity of  $201.35 \pm 9.72$ . The lowest number of eggs were laid on bitter gourd ( $126.59 \pm 3.57$ ).

Laskar (2013) recorded that the egg laying capacity of a sexually mature adult female of *B. cucurbitae* on bitter gourd and pumpkin varied from 90-197 and 98-175, respectively. The hatching percentage was higher on pumpkin as compared to bottle gourd.

Patel and Patel (2018) conducted a research to study the comparative biology of *B. cucurbitae* reared on different cucurbitaceous crops *i.e.*, bitter gourd, bottle

gourd and watermelon and concluded that the hatching percentage was 92, 88 and 80, respectively and the fecundity was 32-35, 42-46 and 50-55 eggs, respectively. Khan and Hugar (2019) studied the biology of *B. cucurbitae* and revealed that the fecundity was around  $60.4 \pm 4.8$ , hatching percentage was  $72.1 \pm 2.6$  and the total life cycle was of  $46.59 \pm 9.50$  days.

#### **2.1.10 Sex-ratio**

Narayanan and Batra (1960) reported that out of the 358 fruit flies reared during the period from July to December, the sex ratio was 183:175. However, Shivarkar and Dumbre (1985) revealed the sex ratio of *B. cucurbitae* as 1:0.96.

Laskar (2013) found that the sex ratio varied from host to host. The sex ratio of melon fruit fly reared on bitter gourd and pumpkin was 0.95-1.26 and 0.91-1.12, respectively.

Mir *et al.* (2014) reported that the sex ratio in *B. cucurbitae* was  $1.10 \pm 0.14$ .

Patel and Patel (2018) concluded that the sex ratio of *B. cucurbitae* as 1:0.67, 1:0.56 and 1:0.39 reared on bitter gourd, bottle gourd and watermelon, respectively.

Gaddanakeri and Rolania (2020) found that sex ratio of *B. cucurbitae* (male: female) was 1: 0.84.

#### **2.1.11 Adult longevity**

Ullah *et al.* (2008) concluded that highest longevity of male of *B. cucurbitae* was on squash ( $45.62 \pm 1.51$  days) whereas, on bitter gourd it was the most unsuitable host for male fruit fly survival ( $25.33 \pm 2.0$  days). Female flies have the highest longevity on squash and the lowest on bitter gourd.

Vayssieres *et al.* (2008) concluded that in *B. cucurbitae* 50 percent of the females were still alive after 5 months on cucumber and 60 percent after 6 months on pumpkin at 25°C.

Laskar (2013) reported that longevity of adult of *B. cucurbitae* depends upon the gender of the melon fruit fly and the host on which they are reared. Longevity of male adults were observed longer on bitter gourd ( $31.6 \pm 9.14$  days) as compared

to the ones reared on pumpkin ( $27.2 \pm 7.4$  days). As a whole, female adult lived longer than that of male. Duration of female adult reared on bitter gourd and pumpkin was  $33.2 \pm 6.34$  days and  $30.6 \pm 8.2$  days respectively.

Mir *et al.* (2014) found that *B. cucurbitae* lived for 12-35 days when supplied with water and honey in the ratio of (1:1). However, when they were supplied with water, molasses and proteinex, males lived for  $40.4 \pm 2.9$  and females lived  $48.6 \pm 3.51$  days.

Patel and Patel (2018) reported that adult male longevity of *B. cucurbitae* was  $10.33 \pm 0.61$ ,  $12.81 \pm 0.65$ ,  $13.11 \pm 2.11$  days, while as; adult female longevity was  $15.1 \pm 0.73$ ,  $17.22 \pm 0.83$ ,  $16.86 \pm 2.73$  days reared on bitter gourd, bottle gourd and watermelon.

Akter and Sohel (2020) reported that mean adult longevity of melon fruit fly was  $14.1 \pm 1.28$  days.

## **2.2 To develop management strategy against *Bactrocera cucurbitae* under field conditions.**

### **2.2.1 Management of *Bactrocera cucurbitae* with Bait and Kill Technique**

Bateman (1982) reported that Bait Application Technique (BAT) is capable of eradicating small population outbreaks of *B. cucurbitae* and this technique should be regarded as a primary weapon for an emergency control against any fruit fly pest.

According to Prokopy *et al.* (2003), GF-120 (Fruit fly bait) was tested and shown to be an adequate replacement for organo-phosphates through the Hawaii Area-Wide Fruit Fly programme for *B. cucurbitae*.

Kumar and Agarwal (2005) reported that the formulation of Soya powder (2g) + Cue lure (1ml) as the most effective in male fly annihilation of *B. cucurbitae*.

Thakur and Gupta (2013) reported that protein hydrolysate attracted maximum adults (6.2 fruit flies / 30 minutes) followed by yeast hydrolysate (4.9 fruit flies / 30 minutes) and sugar (3.8 fruit flies / 30 minutes)

Mir *et al.* (2014) reported that maximum fruit flies were trapped in protein hydrolysate (84.0 flies/trap/month) followed by soya powder (71.5flies/trap /month).

### **2.2.2 Evaluation of different sticky cards in capturing *Bactrocera cucurbitae***

Robacker *et al.* (1990) reported that green and yellow sticky traps were the most attractive for both the sexes of Mexican fruit flies followed by amber, orange and fluorescent yellow.

Robacker and Heath (2001) reported that a sticky trap made from fruit fly adhesive paper (FFAP) covered with a plastic mesh was as effective as Pherocon AM traps in capturing Mexican fruit fly, *A. ludens* on citrus orchard in Weslaco, Texas.

Said *et al.* (2016) reported that yellow sticky traps caught more adult fruit flies than other coloured traps. The overall mean catch for yellow sticky trap was the highest *i.e.*, 62.2 flies per trap followed by white and green traps with overall mean catches of 45.3 and 40 adults per trap.

Sardana *et al.* (2020) studied the efficacy of different coloured sticky traps in capturing *B. cucurbitae* in bitter melon and found that highest number of catches was recorded in orange sticky trap followed by yellow and the lowest in blue coloured trap.

### **2.2.3 To evaluate the efficacy of different colour traps in capturing *Bactrocera cucurbitae* in cucumber**

Liburd *et al.* (1998) observed that baited green, red, yellow or blue spheres were more attractive to blue berry maggot, *R. mendax* (Walsh) than baited yellow board traps.

Katsoyannos and Kouloussis (2001) reported that adhesive coated yellow and orange 70 mm diameter plastic spheres trapped the greatest number of *B. oleae* males while, red and black spheres trapped more females.

Madhura (2001) found that deep yellow colour traps attracted maximum number of *Bactrocera* species.

Sarada *et al.* (2001) observed that significantly more number of *B. dorsalis*, *B. correcta* and *B. zonata* were attracted to white and yellow coloured traps followed by green, orange, red and blue, respectively.

Mir *et al.* (2014) reported that yellow and green coloured traps attracted higher number of fruit flies *i.e.*, 44.2 and 32.7 flies/trap/month, respectively.

Kumar and Laskar (2019) conducted an experiment and reported that yellow coloured trap captured significantly highest mean number of *B. cucurbitae* followed by orange, green, red, white, black, transparent and blue coloured traps. When overall mean values of trap-catch were considered, yellow coloured trap attracted highest number of fruit flies (12.72 fruit flies/trap/day) followed by orange coloured trap (10.82 fruit flies/trap/day). The least number of fruit flies was attracted to blue coloured trap (3.97 fruits flies/trap/day) followed by transparent trap (4.74 fruits flies/trap/day).

Ali *et al.* (2020) concluded that Mediterranean fruit fly (*Ceratitidis capitata*) was greatly influenced by the colour of traps. The results showed that the yellow traps attracted highest number of flies 12.16 male / trap / week followed by the white colour 11.75 male / trap / week, and least in green colour (9.68 male /trap / week).The results showed that yellow and white colours proved highly effect to capture the adult fruit flies.

#### **2.2.4 Effect of height of traps in capturing *Bactrocera cucurbitae***

Siddiqui *et al.* (2003) reported that significantly highest number of fruit flies and maximum population was recorded at 10 feet height.

Hassan and Mohammed (2004) carried an experiment for the insect trapping efficiency of various coloured traps in cucumber. The treatments involved seven different sticky traps placed at four different heights (0.5, 1.0, 1.5 and 2.0 m above the ground). Significantly more insect pests were trapped on fluorescent yellow at a height of 2 m.

Said *et al.* (2016) conducted an experiment to evaluate the efficiency of traps hung at different heights *i.e.*, 25, 50, 75 and 100 cm above ground in pepper. Traps set up at 25 and 50 cm above ground caught more oriental fruit flies *i.e.*,

187.8 and 171.9 respectively and the least efficient was the trap set up at 100 cm above ground (37.1 flies).

Ragheef and Jassany (2018) reported that highest number of *B. zonata* males were captured in the traps at 2m and 1.5m height.

## Chapter-3

### MATERIALS AND METHODS

#### 3.1 Biology of *Bactrocera cucurbitae* on cucumber under laboratory conditions

Cucumber fruits infested with *Bactrocera cucurbitae* were collected during the month of June, 2022 from experimental research plot of Division of Entomology and the fruit flies were cultured in the laboratory of Division of Entomology, FoA, Wadura. The infested fruits of cucumber were kept in a tray containing 5cm of sieved soil kept in insect rearing cage (35 cm x 35 cm x 35 cm). After a few days the rotten cucumbers were removed and the soil was sieved to collect the pupae. The pupae were kept individually in glass vials for adult emergence. Freshly emerged adults were confined in rearing cages having semi solid diet of protein hydrolysate. Fresh cucumber fruits were kept in the cage for oviposition. The eggs were detected by cutting the fruit near the oviposition puncture. The eggs were observed under simple microscope and observations on egg count were recorded randomly from ten samples. The eggs were transferred on thin cucumber slices placed on damp filter paper in a Petridish (5 cm diameter). After 4 days of placing the eggs, the maggots were transferred on fresh slices of cucumber and kept in rearing cages. The culture maintained this way was used in biological studies of *B. cucurbitae*.

##### 3.1.1 Incubation period

A batch of ten freshly laid eggs were collected and placed on thin slices of cucumber inside a closed Petridish (5 cm diameter). After 12 hours, number of eggs hatched were recorded till no more eggs were left unhatched and the time elapsed was calculated to work out the incubation period.

### **3.1.2 Maggot period**

The freshly hatched maggots were reared on a bait mixture of water and molasses and kept in a disposable Petridish (10 cm diameter). The maggots were reared till they suspended feeding and stopped movements. The maggots were then transferred in a plastic tray containing sieved soil layer of 5 cm depth. The sand was sieved daily for the collection of pupae. The duration from egg hatching to formation of pupa was taken as maggot period.

### **3.1.3 Prepupal and pupal period**

The 3<sup>rd</sup> instar maggots remained stationary and suspended feeding before ecdysis to pupation. The time period between suspension of bodily movements and ecdysis to pupal stage was recorded as pre-pupal period. The puparia collected from the tray containing sieved soil were kept individually in glass vials with dimensions of 12.5 cm x 4 cm. The open ends of glass vials were covered with thin piece of muslin cloth held in position with a rubber band and pupae were carefully placed under 2 cm thick layer of sieved soil. To evaluate the pupal period the pupae were watched daily till adult emergence. 10 pupae were taken to record the prepupal and pupal period.

### **3.1.4 Pre oviposition, oviposition and post oviposition period**

The pre oviposition was recorded for ten female fruit flies as the time period from adult emergence to initiation of egg laying. Oviposition period was recorded as the initiation of egg laying by a mated female to the cessation of egg laying (in days). Post oviposition period was recorded as the period from the termination of egg laying to the first instar emergence (in days).

### **3.1.5 Fecundity and hatchability**

Ten pairs of *B. cucurbitae* flies were kept in rearing cages containing cucumber fruits. Fecundity was recorded as the total number of eggs laid by a female throughout its oviposition period. A cotton swab soaked in a solution of water and molasses was provided for egg laying of adult female fruit flies. Each such rearing cage represented one replicate. Infested cucumber fruits were removed and examined once in a day to mark the freshly laid eggs. Total

number of eggs laid by each female each day was examined with the help of a hand lens. The number of eggs hatched successfully out of the total number of eggs under observation was recorded as hatchability. The eggs were observed daily till no more eggs remained unhatched.

### **3.1.6 Sex ratio**

A batch of one hundred pupae present in ten lots, each lot containing ten pupae were cultured and watched for adult emergence. The ratio of male and female fruit flies that emerged from the pupal culture constituted the sex ratio. The fruit flies were sexed on the basis of presence or absence of ovipositor and general size. This way mean sex ratio was computed.

### **3.1.7 Adult longevity**

Adult longevity was recorded as the time period from the adult emergence till death. To record the adult longevity, ten pairs of fruit flies (male and female) were cultured and studied. Adults were provided with their natural host (cucumber) as well as a mixture of water and molasses in a ratio of 1:1 placed on cotton swabs on a petri-plate for feeding and the diet was changed daily.

### **3.1.8 Morphological and Morphometric observations of *Bactrocera cucurbitae***

Morphometric observations of different stages of *B. cucurbitae* were carried out using calibrated ocular micrometer and vernier caliper. Ten replicated of each stage *i.e.*, egg, freshly hatched maggots, fully grown maggots, pupae and adult fruit flies were maintained to determine the size, shape, colour, period interval of each stage in days and the data associated with each stage was recorded.

## **3.2 Management strategy for *Bactrocera cucurbitae* under field conditions**

### **3.2.1 Management of *B. cucurbitae* with bait and kill method**

T<sub>1</sub>: Soya powder (10 g) + Cue lure (1 ml) + Dimethoate 30 EC (1 ml)

T<sub>2</sub>: Molasses (10 ml) + Cue lure (1 ml) + Dimethoate 30 EC (1 ml)

T<sub>3</sub>: Jaggery (10 g) + Cue lure (1 ml) + Dimethoate 30 EC (1 ml)

T<sub>4</sub>: Protein hydrolysate (10 ml) + Cue lure (1 ml) + Dimethoate 30 EC (1 ml)

T<sub>5</sub>: Cue lure (1 ml) + Dimethoate 30 EC (1 ml) (as control)

Experiment was conducted in the research farm of Division of Entomology, FoA-Wadura (SKUAST-Kashmir) in the peak fruiting season of cucumber (1<sup>st</sup> week of July to 4<sup>th</sup> week of October, 2022). Four different baits comprised of female food lures mixed with 1 ml of Dimethoate 30 EC and 1ml of Cue-lure (Attractant), were used during this experiment. These different bait combinations were suspended in multi-lure type traps. The baited traps were hung from the grid support of the cucumber vines at 1.5 m height above the ground level. Trap wise counts were made at weekly intervals from July to October and the data pertaining to the efficacy of different treatments were recorded and analysed statistically.

Replications – 4

Design – RBD

### **3.2.2. To evaluate the efficacy of different sticky cards in capturing**

#### ***Bactrocera cucurbitae* in cucumber**

T<sub>1</sub>: Yellow sticky trap

T<sub>2</sub>: Blue sticky trap

T<sub>3</sub>: Green sticky trap

T<sub>4</sub>: White sticky trap

Four sticky traps *viz.* Yellow, Green, Blue and White of size 28 x 11 cm, were placed at a height of 1.5m from the ground level and evaluated in cucumber field at SKUAST-K, FoA, Wadura during 2022. The fruit flies were collected at weekly intervals from July to October and the number of fruit flies caught per trap per week was recorded as total catch per trap.

Replications- 5

Design-RBD

### **3.2.3 To evaluate the effect of colour on trap catch and monitoring of adult**

#### ***Bactrocera cucurbitae.***

T<sub>1</sub>: Yellow sphere trap

T<sub>2</sub>: Blue sphere trap

T<sub>3</sub>: Green sphere trap

T<sub>4</sub>: Orange sphere trap

Four coloured sphere traps *viz.* Yellow, Green, Blue and Orange were placed at a height of 1.5 m from the ground level. Traps were recharged with Cue lure (1 ml) and Dimethoate 30 EC (0.5 ml) at weekly intervals. Care was taken to maintain a distance of 50 m between two traps to avoid trap interference and the position of traps was randomly changed at fortnightly intervals to nullify the effect of position of trap in attracting fruit flies.

Replications-5

Design- RBD

### **3.2.4 Effect of height in capturing *Bactrocera cucurbitae* in cucumber**

T<sub>1</sub>: 0.5m

T<sub>2</sub>: 1.0m

T<sub>3</sub>:1.5m

T<sub>4</sub>: 2.0m

T<sub>5</sub>: 2.5m

To workout the optimum height for catching maximum *Bactrocera cucurbitae*, the traps were hung at five different heights above the ground. Traps were baited with 3 ml of 4:1 mixture of Cue-lure + Dimethoate 30 EC and cleared at weekly intervals.

Replications – 5

Design - RBD

## Chapter-4

### EXPERIMENTAL FINDINGS

The results pertaining to various aspects of the present investigations related to the biology and management of *Bactrocera cucurbitae* are presented under the following headings:

#### 4.1 Biology of *B. cucurbitae* on cucumber

During the course of present investigation, cucumber fruits infested with maggots of *B. cucurbitae* were collected from the field during the year 2022. The infested fruits were kept in rearing cages for raising the culture to study the biology of the melon fruit fly, *Bactrocera cucurbitae*.

##### 4.1.1 Incubation period

The present findings revealed that the incubation period ranged from 1.2-3.0 days with a mean of  $2.01 \pm 0.67$  days (Table 1).

##### 4.1.2 Maggot period

The average duration of 1<sup>st</sup>, 2<sup>nd</sup> and 3<sup>rd</sup> instar maggot was  $1.08 \pm 0.52$ ,  $1.94 \pm 0.68$  and  $2.43 \pm 0.43$  days, respectively. The total maggot period was recorded  $5.45 \pm 1.28$  days (Table 1).

##### 4.1.3 Prepupal and Pupal period

The duration of pre-pupal and pupal stage came out to be  $1.13 \pm 0.60$  and  $7.79 \pm 1.45$  days, respectively (Table 1).

##### 4.1.4 Adult longevity

Adults were provided with their natural host (cucumber) as well as a mixture of water and molasses in a ratio of 1:1 placed on cotton swabs on a petri-plate for feeding and the diet was changed daily. Adults were also seen feeding on cucumber juice oozing out of the punctures.

Adult longevity was recorded as the time period from the emergence of adults till their death was found different for both sexes. The mean adult longevity of

males and females in days was recorded as  $28.33\pm 6.64$  and  $31.16\pm 5.69$  days, respectively (Table 1).

#### **4.1.5 Oviposition period**

The oviposition period ranged from 10.50-27.0 days with a mean of  $17.57 \pm 5.50$  days.

#### **4.1.6 Fecundity**

The female of *B. cucurbitae* does not lay eggs continuously throughout her life span but at an interval of 2-6 days. *B. cucurbitae* lays its eggs inside the epicarp or mesocarp region of cucumber fruit by puncturing it. After egg deposition the puncture appears like a dark spot with fluid exuding from it, which later dries and appears like a transparent or brownish resinous deposit. The fecundity ranged from 52-90 eggs with a mean of  $72.10\pm 14.20$  eggs (5-15 in cluster).

#### **4.1.7 Sex ratio**

The adult fruit flies that emerged from pupae were examined and sexed on the basis of presence or absence of ovipositor. The sex-ratio (male:female) ranged from 1:1.12 to 1:0.76 or 0.89-1.31 (Table 2).

#### **4.1.8 Morphological and Morphometric observations on *B. cucurbitae***

Morphometric study of different life stages of *B. cucurbitae* was carried out on ten replicates of each stage *i.e.*, egg, maggot, prepupa, pupa and adult for linear measurements, in the laboratory of Division of Entomology during 2022.

##### **4.1.8.1 Egg**

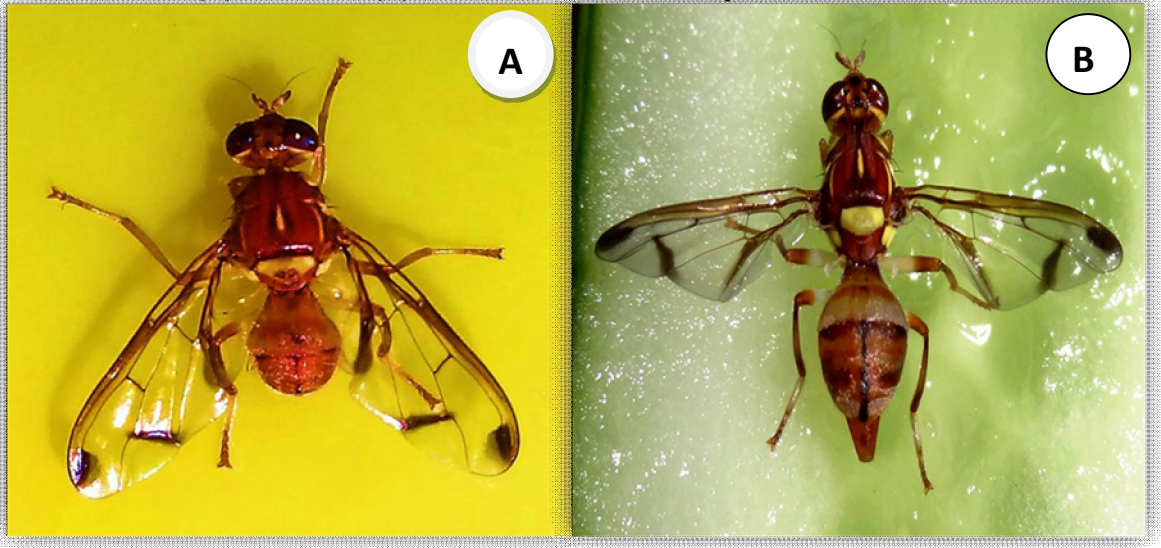
Eggs of *B. cucurbitae* were shiny, white, translucent, slightly curved, tapering at one end and rounded at another end which turned darker as hatching approached. The average length and breadth of egg was  $1.11\pm 0.18$  mm and  $0.27\pm 0.04$  mm, respectively (Table 3).

**Table 1. Developmental attributes of *Bactrocera cucurbitae* (Coquillett) on cucumber during 2022 at FoA Wadura**

Stage	*Range	Mean±SD
Incubation period (days)	1.20-3.00	2.01±0.67
Maggot Period (in days)		
1 <sup>st</sup> instar	0.40-2.00	1.08±0.52
2 <sup>nd</sup> instar	1.00-3.00	1.94±0.68
3 <sup>rd</sup> instar	1.80-3.00	2.43±0.43
Total maggot period	3.20-7.40	5.45±1.28
Prepupal period	0.30-1.90	1.13±0.60
Pupal period	6.00-10.00	7.79±1.45
Adult longevity (days)		
Male	18.00-37.00	28.33±6.64
Female	22.00-39.00	31.16±5.69
Temperature (°C)	12.20-27.50	20.46±4.57
Relative humidity (%)	50-91	69.55±9.33

\*Mean of 10 replications

**Plate-1: (A) Male and (B) Female of melon fruit fly, *Bactrocera cucurbitae***



**Table 2. Biological attributes of *Bactrocera cucurbitae* (Coquillett) on cucumber during 2022 at FoA, Wadura**

<b>Stage</b>	<b>Range</b>	<b>Mean <math>\pm</math> SD</b>
Oviposition period (days)	0.50-27.00	17.57 $\pm$ 5.50
Fecundity	2-90	72.10 $\pm$ 14.20
Sex ratio	0.89-1.31	0.99 $\pm$ 0.12
Temperature ( $^{\circ}$ C)	2.20-27.50	20.46 $\pm$ 4.57
Relative humidity (%)	50-91	69.55 $\pm$ 9.33

\*Mean of 10 replications

#### **4.1.8.2 Maggot**

There are three apodous larval instars and all the three instars differ in their size and structure. The observations were carried at different times in a day. The 1<sup>st</sup> instars were transparent and gut was visible. The 2<sup>nd</sup> instars were ellipsoidal in shape, translucent, elongate and creamy white in colour. The mean length and breadth of 1<sup>st</sup> instar was  $2.30 \pm 0.98$  mm and  $0.35 \pm 0.10$  mm, respectively (Table 3) while as, for the 2<sup>nd</sup> instar maggot the mean length and breadth was  $5.62 \pm 1.24$  mm and  $1.25 \pm 0.16$  mm, respectively (Table 3). The 3<sup>rd</sup> instar had a peculiar habit of curving itself and leaping into air to a distance of 15-20 cm. This special habit enables them to displace themselves from the fruit to the site of pupation (soil). The average length and breadth of fully grown 3<sup>rd</sup> instar maggot was  $8.95 \pm 0.95$  mm and  $2.08 \pm 0.46$  mm, respectively (Table 3).

#### **4.1.8.3 Pre-pupa**

Pre-pupa was slightly bent in position, became inactive and stopped feeding. The average length and breadth of pre-pupa was  $6.82 \pm 0.39$  mm and  $2.19 \pm 0.22$  mm, respectively (Table 3).

#### **4.1.8.4 Pupa**

Freshly formed pupae were yellowish white in colour. After few hours the colour of pupae changed to brown. The pupae were barrel shaped, cylindrical with ventral and dorsal surface having distinct eleven segments. The pupa has a black dot on the posterior end which distinguishes it from the pupae of other species. The mean length and breadth of pupae were  $5.09 \pm 0.44$  mm and  $2.04 \pm 0.26$  mm, respectively (Table 3).

#### **4.1.8.5 Adult**

The freshly emerged adults were inactive, pale yellowish in colour and their wings glued to their bodies. After 2-3 hours the adults became active with a

normal reddish brown colour. Adult females were larger than males and were distinguished by the presence of pointed ovipositor at the tip of abdomen. The average length and breadth (with expanded wings) of male *B. cucurbitae* was  $7.48 \pm 0.74$  mm and  $12.39 \pm 1.56$  mm, while as, the average length and breadth (with expanded wings) of female was  $9.22 \pm 0.75$  mm and  $15.37 \pm 1.08$  mm, respectively (Table 3).





Plate 2: (A) Eggs (B) Maggot and (C) Pupae of melon fruit fly, *Bactrocera cucurbitae*

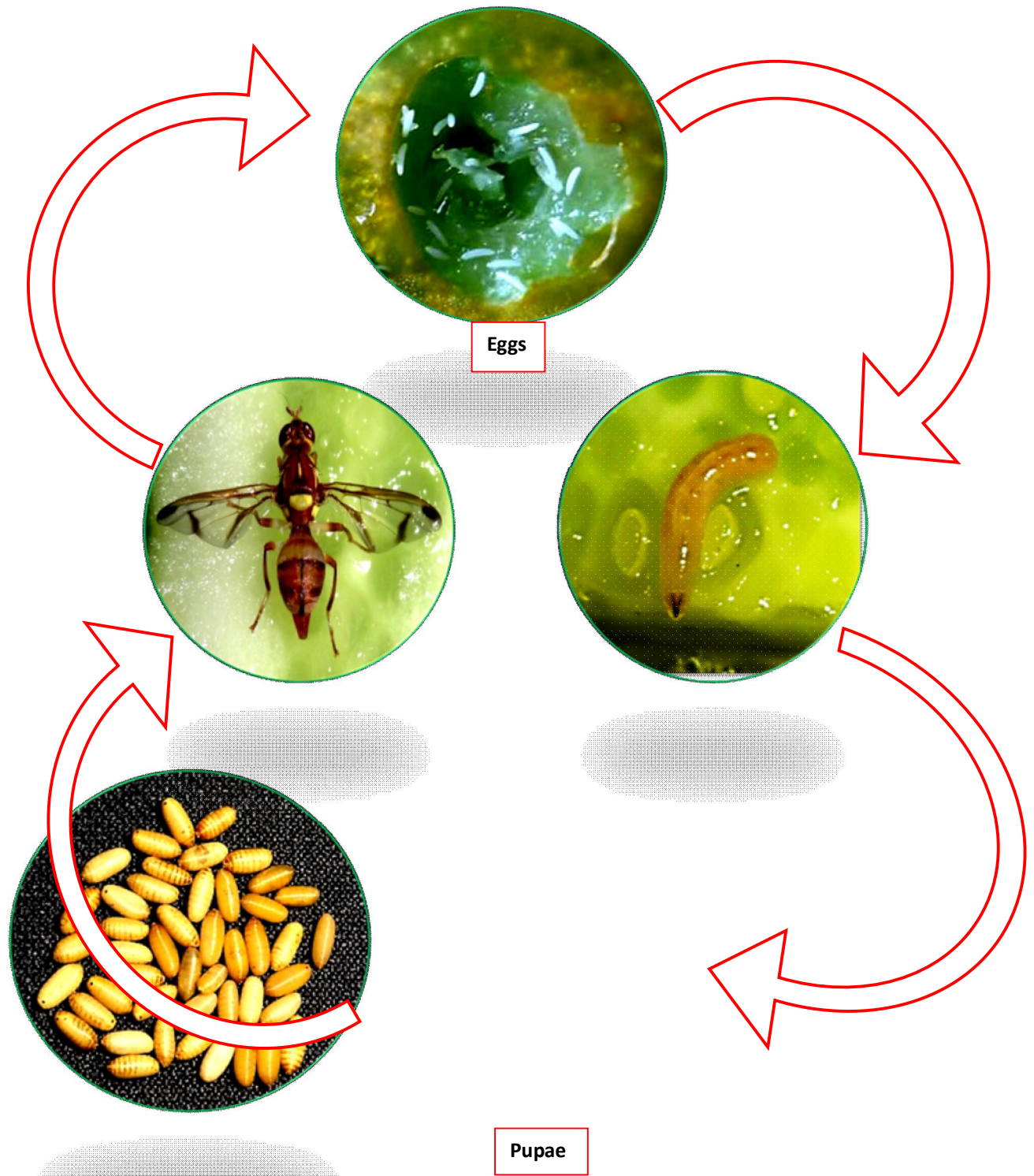


Plate-3 Life cycle of melon fruit fly, *Bactrocera cucurbitae*

**Table 3. Morphometrics of *Bactrocera cucurbitae* (Coquillett) on cucumber during 2022 at FoA Wadura**

Stage	Length (mm)		Breadth (mm)	
	*Range	Mean±SD	Range	Mean±SD
<b>Egg</b>	0.94-1.38	1.11±0.18	0.22-0.34	0.27±0.04
<b>Maggot</b>				
1 <sup>st</sup> Instar	1.22-3.59	2.30±0.98	0.20-0.54	0.35±0.10
2 <sup>nd</sup> Instar	4.10-7.40	5.62±1.24	1.00-1.43	1.25±0.16
3 <sup>rd</sup> Instar	7.60-10.80	8.95±0.95	1.40-2.80	2.08±0.46
Prepupa	6.30-7.40	6.82±0.39	1.90-2.50	2.19±0.22
Pupa	4.50-5.80	5.09±0.44	1.70-2.50	2.04-0.26
<b>Adult (with expanded wings)</b>				
Male	6.40-8.50	7.48±0.74	10.7-14.6	12.39±1.56
Female	8.40-10.50	9.22±0.75	13.9-17	15.37±1.08

\*Mean of 10 replications

## **4.2 Management strategy for *Bactrocera cucurbitae***

During the present course of investigations, field experiments were conducted at FoA Wadura to develop an eco-friendly integrated pest management strategy for *B. cucurbitae* on cucumber during 2022.

### **1.2.1 Management of *Bactrocera cucurbitae* with bait and kill technique (BAT)**

The adult fruit flies trapped during four months *i.e.*, July to October during the year 2022 showed that the trapping was maximum in the month of August with an average of 25.29 flies/trap/month and minimum in October (3.03 flies/trap/month). Significant differences among the treatments tested for trapping adult fruit flies were observed. During July to October 2022, maximum flies were trapped in T<sub>4</sub> (21.55 flies /trap) followed by T<sub>1</sub> (17.15 flies /trap) and T<sub>2</sub>(15.76 flies /trap) and least number of flies were trapped in T<sub>5</sub> (7.59 flies/trap).

Fruit flies caught by protein hydrolysate were significantly higher in number than other bait treatments. Combinations of different bait treatments and months together had significant influence in attracting fruit flies with highest catches in T<sub>4</sub> during the month of August(34.56 flies/trap/month) and lowest in T<sub>5</sub> during the month of October(1.75 flies/trap/month).The data indicated that cue-lure alone did not serve as an effective component compared to all other treatments. Protein hydrolysate and soya powder which are good source of protein were used as bait components in treatments T<sub>4</sub> and T<sub>1</sub> caught higher number of flies as compared to other treatments. There was a clear difference in the number of flies trapped during the four months as given in Table 4.

**Table 4. Efficacy of Bait and Kill Technique (BAT) against *Bactrocera cucurbitae* during 2022 at FoA Wadura**

<b>Treatments</b>	<b>July (Flies trapped)</b>	<b>August (Flies trapped)</b>	<b>September (Flies trapped)</b>	<b>October (Flies trapped)</b>	<b>Mean</b>
T <sub>1</sub>	11.25 (3.48)	26.28 (5.3)	27.31 (5.31)	3.62 (2.14)	17.11
T <sub>2</sub>	9.93 (3.3)	25.37 (5.13)	24.81 (5.07)	2.93 (1.98)	15.76
T <sub>3</sub>	7.5 (2.9)	25.56 (5.13)	22.87 (4.87)	2.18 (1.77)	14.52
T <sub>4</sub>	13.06 (3.72)	34.56 (5.96)	33.93 (5.9)	4.68 (2.37)	21.55
T <sub>5</sub> (Control)	2.37 (1.82)	14.68 (3.95)	11.56 (3.53)	1.75 (1.65)	7.59
<b>Mean</b>	8.82	25.29	24.09	3.03	
CD (P≤0.05)	0.84	5.00	4.26	3.68	

\*Mean of 4 replications

Figures in parenthesis are square root transformed values

T<sub>1</sub>: Soya powder (10 g) + Cue-lure (1 ml) +Dimethoate 30 EC (1 ml)

T<sub>2</sub>: Molasses (10 ml) + Cue-lure (1ml) + Dimethoate 30EC (1 ml)

T<sub>3</sub>: Jaggery (10 g) +Cue-lure (1ml) +Dimethoate 30 EC (1 ml)

T<sub>4</sub>: Protein hydrolysate (10 ml) + Cue-lure (1 ml) +Dimethoate 30 EC (1 ml)

T<sub>5</sub>: Cue-lure (1 ml) + Dimethoate 30 EC (1 ml) (As control)

### **1.2.2 To evaluate efficacy of different sticky cards in capturing *Bactrocera cucurbitae* in cucumber**

Yellow and green sticky cards were found effective and captured higher number of fruit flies 12.27 and 10.06/trap followed by white sticky card with average of 5.65 flies/trap during July to October 2022 and minimum number of flies was captured by blue sticky card with average of 4.45 flies/trap. Month wise data on fruit fly trapping revealed that maximum number of flies were trapped in August (13.23 flies/trap) and minimum in October (3.63 flies/trap). Colour of sticky cards and months together had significant effect in attracting fruit flies with highest catches in yellow sticky card in August (18.95 flies/trap) and lowest (1.40 flies/trap) in blue sticky card during October 2022 (Table 5).

### **1.2.3 To evaluate the efficacy of different coloured sphere traps in capturing *Bactrocera cucurbitae* in cucumber**

Month wise trapping of *B. cucurbitae* revealed maximum catches during the month of August with a mean catch of 15.32 flies/trap and minimum during the month of October with a mean catch of 6 flies/ trap. Moreover, yellow coloured trap captured significantly highest number of flies (13.16 flies /trap) followed by green (10.78 flies/trap) and blue trap (8.67 flies/trap) during July to October 2022. However, minimum number of flies were trapped in orange coloured trap(6.37 flies/trap).Colour of traps and months together had significant influence in attracting fruit flies with highest catch in yellow during August (19.95 flies/trap) and minimum in orange trap during the month of October (3.5 flies/trap) (Table 6).

### **4.2.4 Effect of height of trap in capturing *Bactrocera cucurbitae* in cucumber**

Highest number of flies were captured in the manual traps hung at 2 m height from the ground level with a mean catch of 10.74 flies/trap followed by the manual traps hung at 2.5 m and 1.5 m with a mean catch of 8.85 and 6.07 flies /trap, respectively during July to October 2022.

**Table 5. Response of *Bactrocera cucurbitae* towards coloured sticky cards during 2022 at FoA Wadura**

<b>Treatments</b>	<b>July (Flies trapped)</b>	<b>August (Flies trapped)</b>	<b>September (Flies trapped)</b>	<b>October (Flies trapped)</b>	<b>Mean</b>
Yellow sticky card	7.05 (2.80)	18.95 (4.46)	16.85 (4.22)	6.25 (2.68)	12.27
Green sticky card	4.90 (2.40)	15.75 (4.08)	14.90 (3.97)	4.70 (2.35)	10.06
Blue sticky card	2.30 (1.80)	8.40 (3.06)	5.70 (2.58)	1.40 (1.54)	4.45
White sticky card	2.80 (1.90)	9.85 (3.27)	7.75 (2.95)	2.20 (1.77)	5.65
<b>Mean</b>	4.26	13.23	11.30	3.63	
CD (P<0.05)	1.77	2.92	2.48	1.85	

\*Mean of 5 replications

Figures in parenthesis are square root transformed values



**Plate-4: Yellow, white, blue and green sticky cards evaluated against *Bactrocera cucurbitae***

**Table 6. Attraction of *Bactrocera cucurbitae* (Coquillett) towards coloured sphere traps**

<b>Treatments</b>	<b>July (Flies trapped)</b>	<b>August (Flies trapped)</b>	<b>September (Flies trapped)</b>	<b>October (Flies trapped)</b>	<b>Mean</b>
Yellow trap	*10.20 (3.40)	19.95 (4.57)	13.50 (3.8)	9.00 (3.15)	13.16
Green trap	9.00 (3.15)	16.45 (4.16)	10.70 (3.41)	7.00 (2.81)	10.78
Blue trap	6.65 (2.74)	13.80 (3.83)	9.75 (3.27)	4.50 (2.32)	8.67
Orange trap	4.35 (2.30)	11.10 (3.47)	6.55 (2.74)	3.50 (2.11)	6.37
<b>Mean</b>	7.55	15.32	10.12	6.00	
CD (P≤0.05)	2.52	3.10	1.11	1.89	

\*Mean of 5 replications

Figures in parenthesis are square root transformed values



**Plate-5: Evaluation of yellow, green, blue and orange sphere traps against *Bactrocera cucurbitae***

**Table 7. Effect of height of transparent manual trap in capturing *Bactrocera cucurbitae* during 2022 at FoA Wadura**

<b>Treatment (Height in metres)</b>	<b>July (Flies trapped)</b>	<b>August (Flies trapped)</b>	<b>September (Flies trapped)</b>	<b>October (Flies trapped)</b>	<b>Mean</b>
0.5	*2.43 (1.83)	8.43 (3.06)	8.06 (2.99)	1.37 (1.53)	5.07
1.0	1.50 (1.57)	6.18 (2.67)	5.31 (2.51)	1.00 (1.41)	3.49
1.5	3.31 (2.05)	10.12 (3.32)	9.25 (3.18)	1.62 (1.61)	6.07
2.0	5.43 (2.53)	17.5 (4.29)	17.31 (4.27)	2.75 (1.93)	10.74
2.5	3.93 (2.21)	15.00 (3.98)	14.31 (3.90)	2.18 (1.77)	8.85
<b>Mean</b>	3.32	11.44	10.84	1.78	
CD (P≤0.05)	0.80	2.68	2.52	1.47	

\*Mean of 4 replications

Figures in parenthesis are square root transformed values



**(A) Installation of transparent manual traps**



**(B) Installation of steiner traps**

**Plate-6. Installation of transparent manual traps and steiner traps**

Minimum number of flies were attracted by the manual trap hung at 1m from the ground level with a mean catch of 3.49 flies/trap. Month wise trapping of fruit flies revealed that maximum number of flies were caught during the month of August with an average of 11.44 flies per trap followed by September (10.84 flies /trap) and minimum during the month of October (1.78 flies /trap). Height of traps and months together had significant influence in attracting fruit flies with highest catch at 2 m height during August (17.5 flies/trap) followed by 17.31 flies/trap in September and lowest catch at 1m height during the month of October (1 fly /trap) (Table 7).

## Chapter-5

### DISCUSSION

The present investigation entitled “Studies on Biology and Management of Melon fruit fly, *Bactrocera cucurbitae* (Coquillett) on Cucumber” was carried during 2022 at the Division of Entomology, SKUAST-K, FoA Wadura. The findings of the present investigation are thoroughly discussed in the light of available scientific evidences as follows:

#### **5.1 Biology of *Bactrocera cucurbitae* on cucumber under laboratory condition**

##### **5.1.1 Incubation period**

The present finding regarding incubation period of *B. cucurbitae* are almost similar to that of Akter and Sohel (2020) (1-2 days) and also with the findings of Khan and Hugar (2019) ( $1.9 \pm 0.27$  days). It is also in close proximity with earlier findings of Mir *et al.* (2014) (12-24 hrs.). Dhillon *et al.* (2005) reported the incubation period of *B. cucurbitae* to be 4-4.2, 1.1-1.8 and 1-5.1 days on cucumber, sponge gourd and bitter gourd, respectively. Shivayya *et al.* (2007) observed that the incubation period of *B. cucurbitae* as 1.08-1.5 days. Vargas *et al.* (1984) and Vishwa (2005) reported the incubation period of 1-9 days, which varies greatly depending upon the temperature and relative humidity. Lanjar *et al.* (2013) and Gaddanakeri and Rolania (2020) reported that the incubation period of melon fruit fly as 12-24 hours when reared on muskmelon and bitter gourd, respectively while as, Laskar (2013) reported that incubation period varied from 1.5-2 days and 1.5-2.5 days when reared on bitter gourd and pumpkin, respectively which greatly supports the results of current investigation.

##### **5.1.2 Maggot period**

The current findings related to larval duration is almost similar to those of Laskar (2013) and Akter and Sohel (2020). Gaddanakeri and Rolania (2020) reported that the total maggot period to be  $5.8 \pm 0.78$  days, with duration of 1<sup>st</sup>, 2<sup>nd</sup> and 3<sup>rd</sup> instars ranging from 0.5-1, 1.5-3 and 2-3 days which are almost in accordance

with the current findings. The larval period lasted for 3-6 days on different cucurbit species (Chelliah, 1970; Koul and Bhagat, 1994 ; Gupta and Verma,1995), which strongly supports the current investigations. However, Khan and Hugar (2018) reported the total maggot period to be  $12.08 \pm 0.98$  days which is contrary to the present findings. The maggot period calculated by Singh and Teotia (1970) was 5-11 days, Doharey (1983) found out the maggot period to be 3-8 days, 5.5- 7.5 days by Shivayya *et al.* (2007), 2.8-7.6 days by Patel and Patel (1998), 6.15 days by Shivarkar and Dumbre (1985) and 11.1 days by Borah and Dutta (1996). The difference in maggot period as reported by different researchers is because of difference in temperature, relative humidity, nature of host *etc.*

### **5.1.3 Pre-pupal and pupal period**

The current findings for pre pupal and pupal period are almost in accordance with those of Akter and Sohel (2020) *i.e.*, 0.5-1 days and 8-10 days , respectively. The duration of pupal period lasted for 6-8 days according to the investigations done by Gaddanakeri and Rolania (2020) which is in close proximity to the current findings. According to Laskar (2013), the pupal stage of melon fruit fly varied from 6-8 days on both bitter gourd and pumpkin, however, it took a little bit more time to complete the pupal stage on pumpkin than on bitter gourd and he also reported that the pre pupal stage lasts less than a day and the duration of pre pupal stage was same on bitter gourd and pumpkin *i.e.*, 0.5-1 day, which also supports the current findings. The pupal period of *B. cucurbitae* found by other workers at different climatic region in different parts of the country was 5-8 days (Singh and Teotia, 1970), 7 days (Doharey, 1983) , 6.19-14.63 days (Patel and Patel,1998) ,7-10.7 days (Shivayya *et al.*, 2007),  $7.3 \pm 0.23$  days (Manzar and Srivastava, 2009), 6.55 days (Shivarkar and Dumbre, 1985) which is almost similar to the current findings. Pupal period lasts for 15 days (winter season) and 6-9 days (rainy season) (Narayanan and Batra, 1960).

### **5.1.4 Oviposition period**

Oviposition period is the duration ranging between the initiation of egg laying to the termination of egg laying by a female. The oviposition period (in

days) during the present investigation ranged from 10.5-27.0 days which is almost in consistent with the findings of Gaddanakeri and Rolania (2020)*i.e.*, 10-24 days, Lanjar *et al.* (2013)(12-28 days) and Koul and Bhagat(1994) 12-28 days when reared on bitter gourd, cucumber and Indian squash.

#### **5.1.5 Fecundity**

It refers to the total number of eggs laid by a single female throughout its oviposition period. The range of fecundity of female *B. cucurbitae* during the current investigation came out to be 52-90 eggs which are in close conformity with those of Lanjar *et al.* (2013) and Mir *et al.* (2014). Gaddanakeri and Rolania (2020) reported the fecundity to be slightly higher *i.e.*, 80-108 eggs when reared on bitter gourd. However, investigations of Laskar (2013), Butani (1975) and Koul and Bhagat (1994) revealed that the 90-197, 200 and 120-250 eggs laid by female, when reared on bitter gourd and bottle gourd, respectively, which is much higher than the current findings. Fecundity also depends upon the temperature and maximum production of eggs takes place within a temperature range of 13.4-29.3°C. Protein intake by fruit flies is necessary for egg production, juvenile hormone and ecdysone production. Other factors for the huge difference in egg production of fruit flies are polygynandry, where both males and females mate repeatedly. In some species, the level of polygynandry differs, which ranges from some species occasionally mating with a second male to those species that mate with a number of males throughout their life span (Reguera *et al.*, 2004).

#### **5.1.6 Sex-ratio**

Sex-ratio constituted the ratio of males to the females that emerged from the same lot of pupae. Newly emerged adults were sexed based on the presence or absence of ovipositor. The range of current sex-ratio related to melon fruit flies was 1:1.12 to 1:0.76 and was female oriented which is almost in consistent with that of Sisodiya (2007) who reported the sex ratio to be 1:1.28 on bitter gourd. Regardless of the host plant, *B. zonata* and *B. cucurbitae* produced a higher

proportion of females while using banana, apple, orange, bitter gourd, pumpkin and sponge gourd as host (Saeed *et al.*, 2022), similar observations have been recorded by Prokopy *et al.*, 2003; Barry *et al.*, 2006 while rearing *B. cucurbitae* using cucumber and melon plants as host all of which are in consistent with the present findings. Sex ratio was male oriented in the investigations of Gaddanakeri and Rolania (2020), Patel (1989), Patel and Patel (2018) which is contrary to the current investigations. Seasonal fluctuations (temperature, relative humidity, rainfall) and type of food available also decide the sex ratio of *B. cucurbitae*.

#### **5.1.7 Adult longevity**

The adult male and female longevity in the current observations ranged from 18-37 and 22-39 days, respectively. These observations are supported by those of Mir *et al.* (2014) *i.e.*, 15-40 days and 28-40 days for male and female when reared on water + molasses (1:1). Fukai (1938) reported that if fed on fruit juices the adults will survive for a year at room temperature.

#### **5.1.8 Morphological and Morphometric observations on *B. cucurbitae***

The shape, size and colour of eggs, maggots, prepupa, pupa and adult during the course of investigation are almost similar to the findings of Gaddanakeri and Rolania (2020), Desai *et al.* (2018), Das *et al.* (2017), Laskar (2013), Dhillon *et al.* (2005), Koul and Bhagat (1994), Mir *et al.* (2014), Waseem *et al.* (2012), Shivayya *et al.* (2007) and Singh *et al.* (2000).

### **5.2 Management strategy for *Bactrocera cucurbitae***

#### **5.2.1 Efficacy of bait and kill method against *Bactrocera cucurbitae***

Fruit flies require protein for full ovarian development and production of eggs, thus they readily feed on a protein source (Vargas *et al.*, 2015). Adults go through maturation period for which they need carbohydrates and water to survive. Ammonia serves as an important component in the attraction of fruit flies (Lasa and Williams, 2021) which is also released during the bacterial

decomposition of fruit juices and from protein rich food sources (Prokopy and Roitberg, 1984). Proteinaceous food sources have a strong effect on the behaviour and physiology of tephritid flies (Kaspi *et al.*, 2000; Yuval *et al.*, 2007) and this influence on the behavior of fruit flies is based on the need of protein for egg production (Epsky *et al.*, 2014; Pinero *et al.*, 2015). Thus use of protein baits (Protein + Toxicant) is an effective method for fruit fly control (Vargas *et al.*, 2001). Bait sprays from which ammonia is produced mainly attract female fruit flies causing them to ingest the protein along with a lethal dose of insecticide (Mangan, 2009; Mangan *et al.*, 2014).

During the current investigation, protein hydrolysate, soya powder and molasses as food baits when used with cue-lure were effective in attracting *B. cucurbitae*, however protein hydrolysate when used with cue-lure proved more promising in attracting *B. cucurbitae*. The current investigation is supported by the results of Tamori and Iraha (1986) who concluded that when protein hydrolysate and water in the ratio of 1:50 proved to be the best for attracting *B. cucurbitae*. It was also found that protein hydrolysate as bait along with an insecticide was very effective in checking the oviposition of *B. dorsalis* in mango fruits (Gupta, 1958) which supports the current findings. The present investigations are also in conformity with the recommendations of Dale and Nair (1966) and Gupta and Verma (1982).

### **5.2.2 To evaluate the efficacy of different sticky cards in capturing *Bactrocera cucurbitae* in cucumber**

The use of sticky traps has been accepted by many researchers as an effective method for the control of fruit flies and various other pests. In the current investigation the most efficient among the sticky cards in capturing *B. cucurbitae* was yellow sticky card with a mean catch of 12.27 flies/trap followed by green (10.06 flies/trap) during July to October 2022. Said *et al.* (2016) also reported yellow traps as most attractive to fruit flies which trapped the highest number of flies than any other trap and the least was captured by blue trap, which supports the current investigation. Better efficacy of yellow sticky card over other coloured cards has also been reported by Hill (1986), Robacker *et al.* (1990),

Chua (1993), Heath *et al.* (1997), Howarth and Howarth (2000), Robacker and Rodriguez (2004), Mir *et al.* (2014) and Said *et al.* (2016) strongly supports the current findings.

### **5.2.3 To evaluate the efficacy of coloured sphere traps in capturing *B. cucurbitae* in cucumber**

Yellow coloured traps attracted the highest number of *B. cucurbitae* with a mean catch of 13.16 flies/trap followed by green trap with a mean catch of 10.78 flies/trap during July to October 2022. The present investigation is supported by those of Ragheef *et al.* (2020) who opined that the reason of higher attraction to yellow colour may be due to the colour resemblance with that of plant hosts, which is also confirmed by Papadopoulos *et al.* (2001) who showed that yellow coloured traps are the efficient of all in attracting fruit flies. The current results are also in conformity with those of Prokopy *et al.* (1975), Ballatori *et al.* (1980), Mitchell and Saul (1990), Vargas *et al.* (1991), Jallaluddin *et al.* (1998), Madhura (2001), Sarada *et al.* (2001), Al-joboory (2009), Mir *et al.* (2014), Said *et al.* (2016), Kumar and Laskar (2019) and Ragheef and Jassany (2018). Howarth and Howarth (2000) also found that yellow and white traps attracted more fruit flies than darker coloured traps and suggested that attractiveness was correlated with the intensity of reflectance of trap rather than hue. Stark and Vargas (1992) related more attractiveness of yellow and white coloured traps to the fact that yellow and white coloured flowers are the natural sources of methyl eugenol.

### **5.2.4 Effect of height of trap in capturing *B. cucurbitae* in cucumber**

The results pertaining to mean number of adults caught by manual transparent traps at a height of 0.5 m, 1 m, 1.5 m, 2 m and 2.5 m revealed that more number of adults were caught at 2 m (10.74 flies/trap) followed by 2.5 m (8.85 flies/trap) during July to October 2022. Present findings are almost in accordance with those of Toorani and Abbasipour (2017) and Ragheef and Jassany (2018). However, current findings differ from those of Siddiqui *et al.* (2003), Said *et al.* (2016), Hasnain *et al.* (2017), Mondal *et al.* (2022) who reported that maximum flies were captured in the traps hung at 10 feet height, 5

feet, 25 cm and 150 cm respectively. The current findings also differ greatly with the findings of Apriyadi *et al.* (2021) who reported that fruit flies trapped was inversely related to the height of trap and that more number of male fruit flies were caught when the trap was installed at 50 cm height. To supported their findings they said that more fruit flies fly near the ground as there are more food sources, also the flies that will fall to the ground with the infested fruit will be closer to the traps installed nearer to the ground level.

## Chapter-6

### SUMMARY AND CONCLUSION

The current investigation on the “Studies on Biology and Management of Melon fruit fly, *Bactrocera cucurbitae* on Cucumber” was carried out during the year 2022 at Division of Entomology, FoA, Wadura, SKUAST-K. The salient findings of the present investigation are summarized as :

#### 6.1. Biology of *B. cucurbitae* on cucumber under laboratory conditions

- ✓ Biological parameters of *B. cucurbitae* revealed the data both resembling and differing from the past workers. The average duration of incubation, maggot, pre-pupal and pupal period was found as  $2.01 \pm 0.67$ ,  $5.45 \pm 1.28$ ,  $1.13 \pm 0.60$  and  $7.79 \pm 1.45$  days, respectively. The copulation lasted for 2-5 hours. Duration of oviposition period was 10.5-27 days with a mean of  $17.57 \pm 5.5$  days. Fecundity varied from 52-90 eggs with a mean of  $72.1 \pm 14.2$  eggs. Sex- ratio (male: female) in *B. cucurbitae* was 1:1.12-1:0.76 or 0.89-1.31. The range of male and female longevity when fed with molasses and water was 18-37 and 22-39 days, respectively. Sudden death of flies occurred when water was not available to them.
- ✓ Morphological characters and morphometrics of different life stages of *B. cucurbitae* revealed that the freshly laid eggs were shiny white coloured, translucent, cylindrical shaped, tapering in one end and blunt on the other end. As hatching approached, the blunt end turned darker in colour. The mean length and breadth of the egg was  $1.11 \pm 0.18$  mm and  $0.27 \pm 0.04$  mm, respectively. The first instar maggots were translucent and whitish in colour. The second instar maggots were translucent, ellipsoidal in shape and creamy white coloured. Third instar maggots were pointed anteriorly and blunt posteriorly. Third instar maggots possessed black coloured mouth hooks which extended outside the body while feeding and had a peculiar habit of leaping to a distance. The mean length of first,

second and third instar maggots was  $2.30\pm 0.98$  mm,  $5.62\pm 1.24$  mm and  $8.95\pm 0.95$  mm, respectively. The mean breadth of first, second and third instar maggots was  $0.35\pm 0.10$  mm,  $1.25\pm 0.16$  mm and  $2.08\pm 0.46$  mm, respectively. The mean of the total maggot period was  $5.45\pm 1.28$  days. The pre-pupal stage was identified as the stage when the mature maggots became sluggish, stopped feeding and were slightly bent in position. The mean length and breadth of pre-pupal stage was  $6.82\pm 0.39$  mm and  $2.19\pm 0.22$  mm, respectively. The pre-pupal stage was followed by pupal stage. The pre-pupal stage lasted for  $1.13\pm 0.60$  days. The pupae were cylindrical in shape and 11 segmented. When freshly formed, the pupae were yellowish in colour, but as eclosion approached, the colour gradually changed to brown. The mean length and breadth of pupa was  $5.09\pm 0.44$  mm and  $2.04\pm 0.26$  mm, respectively. The mean pupal period was  $7.79\pm 1.45$  days. The maximum adults emerged between 8:00 to 10:00 am. The freshly emerged adults had their wings adhered to their body and it took 20-30 minutes for them to gain the appearance of an adult. Within 2-3 hours their bodies turned reddish brown in colour. The females had a pointed abdomen because of the presence of ovipositor, which the males were lacking. The females were larger in size than males with a mean length and breadth (with expanded wings) of  $9.22\pm 0.75$  mm and  $15.37\pm 1.08$  mm, respectively. The mean length and breadth of males was  $7.48\pm 0.74$  mm and  $12.39\pm 1.56$  mm, respectively.

## **6.2 Management strategy for *B. cucurbitae***

- ✓ Among all other baits tested, protein hydrolysate and soya powder proved more efficient in attracting fruit flies. The reason for attractiveness of these two is that they are a good source of protein and ammonia is released during the bacterial decomposition of proteins which acts as a strong attractant to many tephritid species. Another reason for their attractiveness is that during their microbial fermentation there is emission

of complex odours containing semiochemicals which attract fruit flies. Molasses and jaggery were moderately attractive to *B. cucurbitae*. The reason is possibly the presence of higher content of sucrose. Mixtures are more effective in attracting *B. cucurbitae* than single compound used separately. For that reason, fruit flies got attracted more when cue-lure mixed with bait was used. Therefore, protein hydrolysate and soya powder proved more effective in attracting fruit flies when mixed with cue-lure.

- ✓ Yellow and green sticky cards proved more effective in attracting *B. cucurbitae*, followed by white cards and blue cards were least effective.
- ✓ In the present studies, *B. cucurbitae* showed higher response to yellow sphere traps followed by green sphere traps.
- ✓ Height of the trap from ground level also had a significant effect on the capture of *B. cucurbitae*. In the current studies, the manual transparent traps hung at 2.0 m height captured highest number of *B. cucurbitae* followed by the traps hung at 2.5 m height.

The following conclusions are drawn based on the findings of the current study:

- ✓ Freshly laid eggs were white, shiny, elongated, tapering at one end and rounded at other end. The mean length and breadth of eggs was  $1.11 \pm 0.18$  mm and  $0.27 \pm 0.04$  mm, respectively. First, second and third instars measured  $2.30 \pm 0.98$  mm,  $5.62 \pm 1.24$  mm and  $8.95 \pm 0.95$  mm in length and  $0.35 \pm 0.10$  mm,  $1.25 \pm 0.16$  mm and  $2.08 \pm 0.46$  mm in breadth, respectively. The mean length and breadth of pupa was  $5.09 \pm 0.44$  mm and  $2.04 \pm 0.26$  mm, respectively.
- ✓ On an average, males measured  $7.48 \pm 0.74$  mm and  $12.39 \pm 1.56$  mm in length and breadth, respectively. The mean length and breadth of females was  $9.22 \pm 0.75$  mm and  $15.37 \pm 1.08$  mm, respectively.

- ✓ The average duration of incubation, maggot, pre-pupal and pupal period was  $2.01 \pm 0.67$ ,  $5.45 \pm 1.28$ ,  $1.13 \pm 0.60$  and  $7.79 \pm 1.45$  days, respectively.
- ✓ The mean oviposition period was  $17.57 \pm 5.5$  days while as, mean fecundity was  $72.1 \pm 14.2$  days.
- ✓ The sex-ratio (Male: Female) ranged from 1:1.12 to 1:0.76 or 0.89-1.31. The mean adult longevity was  $28.33 \pm 6.64$  and  $31.16 \pm 5.69$  days for male and female, respectively when fed with water and molasses. Immediate death of flies occurred when there was no access to water.
- ✓ Use of protein baits such as protein hydrolysate and soya powder proved most effective in attracting fruit flies when used with an attractant (Cue-lure) and a toxicant (insecticide).
- ✓ Yellow and green sticky traps proved to be most effective in attracting fruit flies among the sticky traps. So, they can be used for efficient management of *B. cucurbitae*.
- ✓ Yellow and green sphere traps were more effective in capturing *B. cucurbitae* than other coloured traps. The traps are cheaper, environmentally safe and can be used effectively for controlling fruit flies in farmer's field.
- ✓ For efficient capturing of *B. cucurbitae*, the traps should be hung at 2.0 and 2.5 m from the ground level.

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**CERTIFICATE**

Certified that all the corrections/amendments as suggested by External Examiner **Dr. Abdul Rouf Wani**, Ex Head Division of Entomology, SKUAST-K, FoA Wadura, during viva-voce examination held on 18-09-2023 have been incorporated in the manuscript entitled “**Studies on Biology and Management of Melon fruit fly, *Bactrocera cucurbitae* (Coquillett) on Cucumber**” submitted by **Ms. Rabia Aziz Bhat** (Regd. No. **MSA/2021/1427**)

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