BIO-ECOLOGY HOST PREFERENCE AND MANAGEMENT OF CUCURBIT FRUIT FLY

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CERTIFICATE

*This is to certify that dissertation entitled "**BIO-ECOLOGY HOST PREFERENCE AND MANAGEMENT OF CUCURBIT FRUIT FLY**" submitted to the **Faculty of Agriculture,** Sher-e-Bangla Agricultural University (SAU), Dhaka in partial fulfillment of the requirements for the degree of **DOCTOR OF PHILOSOPHY IN ENTOMOLOGY,** embodies the result of a piece of bona fide research work carried out by **MONOWARA YESMIN, Registration no.* **26161/00458** *under my supervision and guidance. No part of the dissertation has been submitted for any other degree or diploma.*

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

Dated: June, 2019
Place: Dhaka, Bangladesh

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DEDICATED
TO
MY BELOVED
PARENTS

ACRONYMS

Abbreviation	:	Full meaning
AEZ	:	Agro-Ecological Zone
ANOVA	:	Analysis of Variance
BARI	:	Bangladesh Agricultural Research Institute
BARC	:	Bangladesh Agricultural Research Council
cm	:	Centimeter
CRD	:	Complete Randomize Design
DAT	:	Days after transplanting
DMP	:	Dimethoxy Phenol
EC	:	Emalcifiable Concentrate
ECF	:	E-coniferyl alcohol
g/gm	:	Gram
ha	:	Hectare
IPM	:	Integrated Pest Management
Kg	:	Kilo gram
L	:	Liter
LD	:	Lethal Dose
LSD	:	Least Significant Difference
m	:	Meter
ME	:	Methyl Ester
ml	:	Milliliter
mm	:	Millimeter
MSG	:	Mashed Sweet Gourd
RCBD	:	Randomized Complete Block Design
RH	:	Relative Humidity
SAU	:	Sher-e-Bangla Agricultural University
SD	:	Standard Deviation
SP	:	Soluble Powder
Tk	:	Taka
USA	:	United States of America

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MONOWARA YESMIN

ABSTRACT

Thestudy was conducted in the experimental field and laboratory of Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka, Bangladesh, during March 2016 to August 2018 to evaluate bio-ecology, host preference and management of cucurbit fruit fly. In Bangladesh, farmers were faced problem in cultivation of cucurbitaceous crops in the field due to cucurbit fruit fly (*Bactrocera cucurbitae*), the main insect pest of cucurbitaceous crops.The study revealed that, cucurbit fruit fly can attack all types of cucurbitaceous crops. But the infestation become low in kharif season and high in rabi season. Among different types of cucurbitaceous crops cucurbit fruit fly attacks more in bitter gourd and less in sweet gourd. In bio-ecology study, theaverage days for egg incubation (1.7 and 2.7 days), larval period (4.3 and 5.5 days), pupal period (5.9 and 9.8 days),male adult longevity (5.9 and 13.3 days) and female adult longevity (6.7 and 15.8 days) of cucurbit fruit fly were observed at room temperature(±30℃ and ± 85 RH) and laboratory condition(25℃ and 80% RH), respectively.Average ovipositional period of adult female cucurbit fruit flies under room temperature and laboratory condition were 1.4 and 2.9 days, respectively.Average length and breadth of cucurbit fruit flies eggs, larvae, pupa, adult male and female were 1.14 and 0.22,7.9and 2.04,6.2 and 2.38,7.4 and 11.4 and 9.3 and 15.69 mm, respectively.In early, mid and late fruiting stage, the lowest fruit infestation by number and percent fruit infestationby number over control were found in T_2 (6.28 and 76.72%, 12.89 and 83.78% and 14.67 and 83.20%, respectively), using the poison bait trap in the field. In early, mid and late fruiting stage, the lowest fruit infestation by weight and percent fruit infestationby weight over control were found in T_2 (19.30 and 78.73%, 6.18 and 92.48% and 11.98 and 86.63%,

respectively). In early, mid and late fruiting stage, the highest percent edible portion of infested bitter gourd was found in T_2 (66.58%, 75.25% and 75.84%, respectively). The highest number of fruit per plot, single fruit weight, length of single healthy fruit and yield of bitter gourd were found in T_2 (62.33 fruits/plot, 86.04g, 20.66 cm and 17.87 ton/ha, respectively). From the comparative study, poison bait trap (50.00 fruit fly/ trap) was more effective than pheromone trap (19.00 fruit fly/ trap) in terms of capturing adult cucurbit fruit flies throughout the cropping season. The highest benefit cost ratio (BCR) (2.47) was calculated in T_2, where the total adjusted net return was counted as benefit. In the study of IPM packages for cucurbit fruit fly management, the highest captured fruit flies (36.00 flies) was found in IPM package 1comprised with pheromone trap along with poison bait trap.In early, mid and late fruiting stage, the lowest fruit infestation by number, fruit infestation by weight, edible portion of infested fruit, length of single fruit and girth of single fruit were found in IPM package 1 (22.44%, 11.83%, 90.75%, 21.61 cm and 12.78 cm; 16.66%, 17.37%, 87.67%, 23.22 cm and 14.05 cm and 13.68%, 25.87%, 92.91%, 22.75 cm and 13.24 cm, respectively). The highest number of fruit per plot, single fruit weight and yield of bitter gourd were found in IPM package 1 (76.33 fruits/plot, 50.13g and 12.76 ton/ha, respectively)in the field.

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CHAPTER I

INTRODUCTION

Cucurbits are one of the most important vegetables in Bangladesh principally cultivated in summer season during the scarcity of other vegetables. Cucurbits include the largest group of vegetables where the bottle gourd, sweet gourd, bitter gourd, ridge gourd, sponge gourd, teasel gourd, snake gourd, pointed gourd, ash gourd, cucumber, squash, water melon, musk melon are cultivated as major vegetable in Bangladesh (Nasiruddin *et al.* 2004). Cucurbits have a good nutritive value as well as medicinal value. All the cucurbits have a good market value which encourages the farmer to cultivate gourds in large scale (Gopalan *et al.* 1982). The total area of cucurbit crops in 2017-18 was around 77,608 hectares and the total production was about 5,31,076 metric tons (BBS 2019). The summer vegetables play a prime role to the supplement of the shortage during the lag period (Rashid 1993). Some of them can be grown throughout the year because of their photo insensitiveness. The climate of Bangladesh is favorable for growing most of the vegetable crops specially cucurbits. Among the cucurbits bitter gourd, snake gourd and wax gourd are fast growing warm seasonal climbing vegetables crops. They occupy 66 percent of the land under vegetable production in Bangladesh and contribute 11 percent of total vegetable production in the country (IPM CRSP 2004). Area covered by bitter gourd was 10,720 hectare with a total production of 57,908 tons (BBS 2019). In Bangladesh, the production of snake gourd is 37,342 tons over 7,493 ha (BBS 2019).

Cucurbit production is severely affected by a number of insect pests such as red pumpkin beetle, cucurbit fruit fly, epilachna beetle, etc. (Kamal *et al.* 2013). Among them, cucurbits fruit fly, *Bactrocera cucurbitae* (Coquillett)is the major pest responsible for considerable damage of cucurbits (Alam 1969). The genus *Bactrocera* is considered a serious threat of horticultural crops

because of the wide host range of its species and the invasive power of some species within the genus (Clarke *et al.* 2005). Squash (*Cucurbita pepo* L.) is highly prone to damage by the fruit fly (Sapkota *et al.* 2010). Several *Bactrocera* species have been established outside of their native Asian range (Stonehouse *et al.* 1998). Two species of cucurbit fruit fly *viz*., *Bactrocera cucurbitae* and *Dacus caudatus* have been found in Bangladesh (Alam 1964). The *Bactrocera cucurbitae* is dominant in all the locations of Bangladesh followed by *Dacus caudatus* (Akhtaruzzam *et al.* 1999). The pest causing yield loss in cucurbits, and infests all 15 kinds of cucurbit vegetables grown in Bangladesh. A major constraint impaired cucurbit production is high rate of fruit fly infestation. Fruit flies reduce yield as well as the quality of fruits (IPM CRSP 2004). One of the primary cucurbit crops attacked by fruit fly is sweet gourd. Bangladesh produced 112 thousand tons of sweet gourd in kharif season and 191 thousand tons in robi season of 2017-2018 (BBS 2019). Fruit fly infestation was reduced by 53 to 73 percent and yields were raised 1.4 to 2.3 times using the traps (IPM CRSP 2018).

It is important to prevent or minimize pest problems before serious outbreaks occur, to detect pest problems early, and to select appropriate controls. The most important feature of the infestation caused by the fruit fly is to lay eggs beneath the fruit rind of cucurbits by puncturing it and larvae cause damage the pulp of fruits. Traditionally farmers combat this noxious pest using chemical insecticides. But most of the cases, it is not possible to control it due to the larvae live inside the fruits. Even though, farmers use toxic chemicals without considering economic injury level (EIL) of the pest. Thus, toxic chemicals kill natural enemies, regular occurrence of upset and resurgence, residues of pesticides on edible fruits of cucurbits. But the bio-pesticides are completely safe for environment, health and nature. The studies on resistant and/or tolerant varieties as well as resistant/tolerant cucurbitaceous vegetables against cucurbit fruit fly are also

less. Therefore, the cultivation of resistant/tolerant cucurbits as well as judicious use of pesticides along with bio-pesticides is important in the management of resistance to pesticides, conservation of beneficial insects, minimization of environmental hazards, improvement of safety of workers in the field, and overall reduction of farm input costs.

Host preference in herbivorous insects may vary and change in it might have been the critical requirement to initiate the host shifting. Host-specific insects are estimated to represent 25-40% of all animal species (Bush and Butlin 2004). The *Bactrocera* group of fruit flies attracted to a broad variety of hosts. Some fruit flies prefer only one or two host species, or specialize on one group of hosts, while others are generalists and infest as many as 31 host species grown commercially (White and Elson-Harris 1992). Female adult fruit flies are known to make decisions about which fruit to oviposit based on the suitability of the fruit for their offspring's performance (Fontellas-Brandalha and Zucoloto 2004,Joachim-Bravo *et al.* 2001).

Cucurbit fruit fly damages this cucurbits in three ways: i) oviposition injury by the female on fruits and vegetative parts, ii) larval feeding damage on ovaries and fruit pulp and iii) Decomposition of fruit fly damaged fruit tissue by invading saprophytic micro-organism.

Fruit flies produce extensive damage to fruits and vegetables and losses can reach too many folds under serious attack if control measures are not taken timely. Effective crop management of fruit fly is very important for successful cultivation and export of cucurbits. These include: mechanical control, cultural control, biological control and chemical control (Dhillon *et al.* 2005a). The cucurbit 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. In the Commonwealth of the Northern Mariana

Islands, it was detected in 1943 and eradicated by sterile insect release in 1963 (Mitchell 1980,Steiner *et al.* 1965).

Although the rate of attack varies among the crop, infestation reduced both the yield and quality of the cucurbit fruits. Yield losses due to fruit fly infestation vary from 19.19 to 69.96% in different fruits and vegetables (Kabir *et al.* 1991). Depending on the environmental conditions and susceptibility of the crop species, the extent of losses varies between 30 to 100% (Shooker *et al.* 2006;Dhillon *et al.* 2005a, b, c; Gupta and Verma 1992). One of the primary cucurbit crops attacked by fruit fly is sweet gourd. For cucurbits, especially bitter gourd, *Momordica charantia* Linn., the melon fruit fly damage is the major limiting factor in obtaining good quality fruits and high yield (Rabindranath and Pillai 1986, Mote 1975, Lall and Singh 1969, Srinivasan 1959).

The knowledge of biology and different life stages of insect pests is helpful in developing efficient management strategies that will prevent ill effects of insecticides. This study was undertaken to gain precise knowledge of the morphometrics of the various developmental stages, their duration, adult longevity, pre-oviposition and oviposition periods, fecundity and the effect of diet on adult longevity (Mir *et al.* 2014).

Crop protection has long relied on agrochemicals but is now at a defining moment. Although pesticides have been condemned for many years (Carson 1962), the problems encountered with this type of crop protection are becoming more frequent and acute: inefficiency in many situations; resistance to pesticides; soil, water, and air pollution; hazards to human health; and loss of biodiversity (Pimentel 2002). The challenge is now to move from this chemical-based approach to one of pest prevention with more balanced and sustainable agroecosystems. This approach is based on agroecological management of plant and animal communities at extended

scale, spatiotemporal management (Deguine *et al.* 2008). Since the late twentieth century, a strong trend has led researchers and farmers to reduce the use of chemical pesticides, particularly because of its negative impact (on the environment and health) as well as disadvantages (high cost, low efficiency) (Popp *et al.* 2013, Ferron 1999, Pesson 1990).

Integrated Pest Management (IPM) is combination ofsuitable methods to achieve sustainable agricultural production with less damage to the environment (Kogan and Bajwa 1999). While IPM has many definitions, it often includes a diverse mix of approaches to manage pests and keep them below economically damaging levels, using control options that range from cultural to chemical components. In practice, IPM ranges from chemically-based systems that involve the targeted and judicious use of synthetic pesticides, to biologically-intensive approaches that manage pests primarily or fully through nonchemical means (Pedigo and Rice 2008). In recent years, IPM has been seen as an effective method for managing pestiferous fruit flies in an attempt to make fruit production more sustainable (Vargas *et al.* 2008).

While IPM of fruit flies has made many unique contributions to agriculture through the incorporation of ecological principles into pest management, truly effective IPM systems are scarce. A literature search performed in ISI Web of Science in early-March, 2015 returned 4841 articles published since 1984 when “Tephritidae” was searched, and 1543 articles were returned when IPM (focusing on agriculture) was used as key word. Surprisingly, the search returned only 54 articles when both “Tephritidae” and “IPM” were searched and less than half of those truly referred to IPM components. By refining these studies by the term “*Bactrocera*”, only 28 articles were obtained. Clearly, while different search terms certainly would change the corresponding results, it can be seen that IPM of fruit flies, including *Bactrocera* make up only a small proportion of the overall Tephritidae literature.

Studies on resistant and or tolerant varieties as well as resistant/tolerant cucurbitaceous vegetables against cucurbit fruit fly are also less. Therefore, the cultivation of resistant/tolerant cucurbits as well as judicious use of pesticides along with bio-pesticides is important in the management of pesticide resistance, conservation of beneficial insects, minimize environmental hazards, safety of workers in the field, and overall reduction of farm input costs. In view of the above analysis, the present set of research were conducted with following objectives in consideration of host preference and eco-friendly management of cucurbit fruit fly using different management practices along with bio-pesticides.

Overall objectives of the research

1. To evaluate the host preference of cucurbit fruit fly among cucurbitaceous vegetables;
2. To determine the extent of damage of cucurbitaceous vegetables caused by cucurbit fruit fly;
3. To study the bio-ecology of cucurbit fruit fly infesting cucurbitaceous vegetables;
4. To evaluate the efficacy of management practices along with bio-pesticides against cucurbit fruit fly;
5. To integrate the effective management practices and develop an effective IPM package for combating cucurbit fruit fly.

CHAPTER II

REVIEW OF LITERATURE

Cucurbit fruit flies are mostly considered devastating pest because of their wide range of attack capacity of cucurbit fruits. For the purpose of the study, the most relevant information's are given bellow under the following sub-headings:

2.0. Cucurbit fruit fly

The Dipteran family Tephritidae consists of over 4000 species, of which nearly 700 species belong to Dacine fruit flies (Fletcher 1987). Nearly 250 species are of economic importance, and are distributed widely in temperate, sub-tropical, and tropical regions of the world (Christenson and Foote 1960). The first report on melon fruit flies was published by Bezzi (1913) who listed 39 species from India. Forty-three species have been described under the genus *Bactrocera*including*cucurbitae*, *dorsalis*, *zonatus*, *diversus*, *tau*, *oleae*, *opiliae*, *kraussi*, *ferrugineus*, *caudatus*, *ciliatus*, *umbrosus*, *frauenfeldi*, *occipitalis*, *tryoni*, *neohumeralis*, *opiliae*, *jarvisi*, *expandens*, *tenuifascia*, *tsuneonsis*, *latifrons*, *cucumis*, *halfordiae*, *cucuminatus*, *vertebrates*, *frontalis*, *vivittatus*, *amphoratus*, *binotatus*, *umbeluzinus*, *brevis*, *serratus*, *butianus*, *hageni*, *scutellaris*, *aglaia*, *visendus*, *musae*, *newmani*, *savastanoi*, *diversus*, and *minax* from Asia, Africa, and Australia (Fletcher 1987, Munro 1984, Drew and Hooper 1983, Cavalloro 1983, Syed 1969). Amongst these, *Bactrocera cucurbitae* (Coquillett) is a major threat to cucurbits (Shah *et al.* 1948). Senior-White (1924) listed 87 species of Tephritidae in India. Amongst these, the genus, *Bactrocera* (*Dacus*) causes heavy damage to fruits and vegetables in Asia (Nagappan *et al.* 1971). Fruit flies are also serious pests in Pakistan, causing losses at the farm level, and with added losses to traders, retailers and exporters. Small farmers suffer in particular, being the growers of the highly susceptible items and unable to afford enough

protection measures. Losses without control have been estimated as 21% of fruits and 24% of cucurbits in Pakistan (Stonehouse *et al.* 1998).

2.1. Taxonomic position

Cucurbit fruit fly also known as melon fly. The taxonomic position of cucurbit fruit fly is given bellow:

Kingdom: Animalia
Phylum: Arthropoda
Class: Insecta
Order: Diptera
Sub-order: Cyclorrhapha
Family: Tephritidae
Genus: *Bactrocera*
Species: *B. cucurbitae* (Coquillett 1849)

Common names

English: Melon fly, Melon fruit fly, Cucurbit fruit fly
Spanish: Mosca del melon
French: Mouche de melon, Mouche du concombre, Mouche des curcurbitacees
Germany: Tropische Melonenfliege
Italy: Mosca del melone
Japan: Uri-mibae

Synonyms of *Bactrocera cucurbitae*

Chaetodacus cucurbitae
Dacus cucurbitae
Strumeta cucurbitae
Zeugodacus cucurbitae

2.2. Geographical distribution

The Asian parts of the range of this species represent its natural (native) range. In Hawaii it is known to be an introduction, having arrived there late in the 19th century (Clausen 1978). Old records for Australia derive from an eradicated outbreak in Darwin, but as no specimens could be traced this may have been based on a misidentification of *Bactrocera chorista* (White 1999).

The insect has rapidly spread across the African continent and in addition to Kenya it is now known from 20 other countries, including Angola, Benin, Burkina Faso, Cameroon, Comoros Island, Congo, DR Congo, Equatorial Guinea, Ghana, Guinea, Ivory Coast, Mali, Niger, Nigeria, Senegal, Sierra Leone, Sudan, Tanzania, Togo, and Uganda (Ekesi *et al.* 2006, Vayssie` res *et al.* 2005, French 2005, Drew *et al.* 2005).

In Africa, *B. cucurbitae* is found in several countries in East and West Africa, including Benin, Burkina Faso, Cameroon, Gambia, Guinea, Ivory Coast, Mali, Niger, Nigeria, Senegal and Togo in West Africa, and Kenya, Sudan, Tanzania and Uganda in East Africa (Meyer *et al.* 2007).

Table 2.1.Distribution table for *Bactrocera cucurbitae* (CABI 2020)

Continent	Country	Origin	Reference
Africa	Benin	Introduced	Vayssières *et al.* (2007)
	Cameroon	Introduced	EPPO (2014)
	Comoros	Introduced	Msaidie Kassim and Soilihi (2000)
	Congo	Introduced	Vayssières *et al.* (2007)
	Cote d'Ivoire	Introduced	EPPO (2014)
	Egypt	Introduced	Meyer *et al.* (2007)
	Gambia	Introduced	EPPO (2014)
	Ghana	Introduced	EPPO (2014)
	Kenya	Introduced	EPPO (2014)
	Mali	Introduced	EPPO (2014)
	Niger	Introduced	Meyer *et al.* (2007)
	Nigeria	Introduced	Umeh *et al.* (2008)
	Senegal	Introduced	Vayssières *et al.* (2007)
	Somalia	Introduced	EPPO (2014)
	Sudan	Introduced	EPPO (2014)

	Tanzania	Introduced	EPPO (2014)
	Uganda	Introduced	Meyer *et al.* (2007)
Asia	Afghanistan	Introduced	EPPO (2014)
	Bangladesh	Introduced	EPPO (2014)
	Bhutan	Introduced	EPPO (2014)
	Brunei	Introduced	EPPO (2014)
	Cambodia	Introduced	EPPO (2014)
	China	Introduced	EPPO (2014)
	Hong Kong	Introduced	EPPO (2014)
	India	Native	Dhillon *et al.* (2005)
	Indonesia	Introduced	Drew (1982)
	Iran	Introduced	EPPO (2014)
	Japan	Introduced	Koyama *et al.* (2004)
	Laos	Introduced	Drew (1982)
	Malaysia	Introduced	EPPO (2014)
	Myanmar	Introduced	Drew (1982)
	Nepal	Introduced	Drew (1982)
	Oman	Introduced	EPPO (2014)
	Pakistan	Introduced	EPPO (2014)
	Philippines	Introduced	EPPO (2014)
	Saudi Arabia	Introduced	EPPO (2014)
	Singapore	Introduced	AVA (2001)
	Sri Lanka	Introduced	EPPO (2014)
	Taiwan	Introduced	Drew (1982)
	Thailand	Introduced	Drew (1982)
	United Arab Emirates	Introduced	EPPO (2014)
	Vietnam	Introduced	Drew (1982)
North America	United States	Introduced	NAPPO (2010)
Oceania	Australia	Introduced	EPPO (2014)
	Kiribati	Introduced	EPPO (2014)
	Nauru	Introduced	EPPO (2014)
	New Zealand	Introduced	Baker and Cowley (1991)
	Northern Mariana Islands	Introduced	EPPO (2014)
	Papua New Guinea	Introduced	Drew (1982)
	Soloman Islands	Introduced	EPPO (2014)

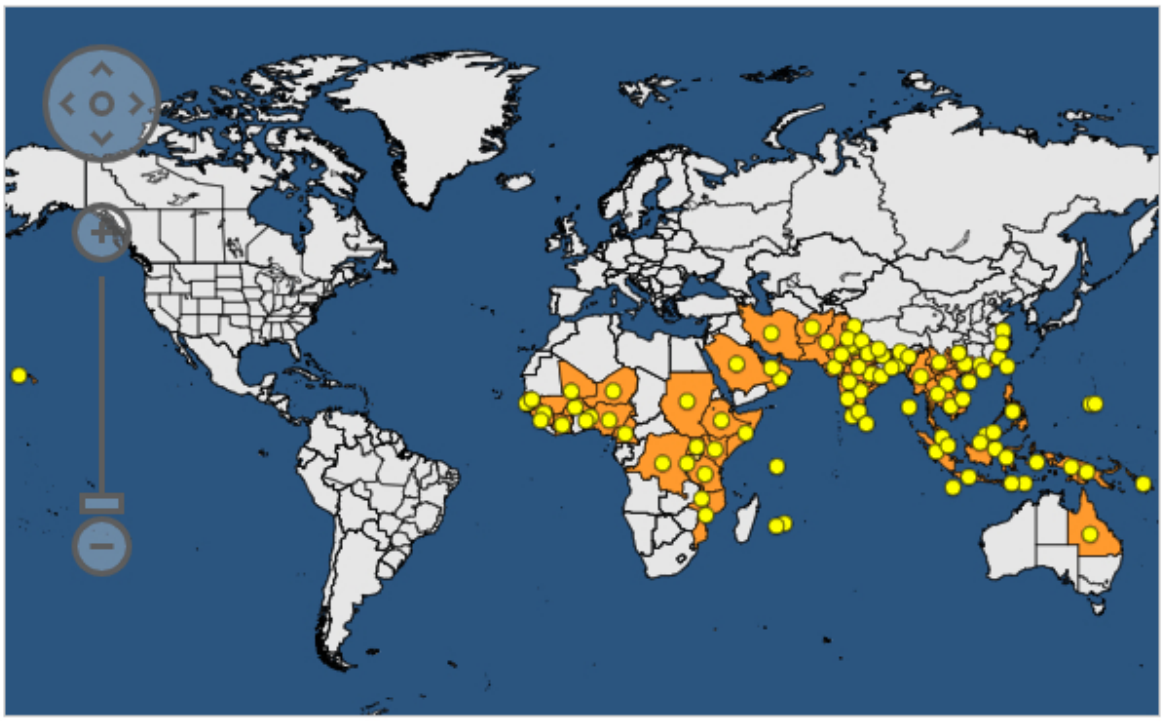


Plate 1. Worldwide distribution of *Bactrocera cucurbitae* (EPPO 2019)

2.3. Morphology

Egg: The eggs of *Bactrocera cucurbitae* were described in detail by Margaritis (1985) and those of other species are probably very similar with the micropyle protruding slightly at the anterior end. The chorion is reticulate. White to yellow-white in colour (CABI 2020, White and Elson-Harris 1997).

Larva: Head: Stomal sensory organ small, completely surrounded by 6-7 large preoral lobes, some bearing serrated edges similar to oral ridges; oral ridges with 17-23 rows of moderately long, uniform, bluntly rounded teeth; accessory plates numerous, with serrated edges and interlocking with oral ridges; mouthhooks large, heavily sclerotized, each with a small, but well-defined preapical tooth.

Thoracic and abdominal segments: anterior portion of T1 with an encircling, broad band of spinules which dorsally and laterally form small plates 7-10 rows deep, becoming discontinuous rows ventrally; T2 with smaller, stouter spinules, forming 5-7 discontinuous rows around anterior portion of segment; T3 similar to T2, but reduced to 4-6 rows. Creeping welts obvious, with 9-13 rows of small spinules. A8 with large well rounded intermediate areas, almost linked by a large, slightly curved, pigmented transverse line (mature larvae only). Tubercles and sensilla well defined.

Anterior spiracles: 16-20 tubules.

Posterior spiracles: spiracular slits large, with heavily sclerotized rimae; about 3 times as long as broad. Spiracular hairs long, fine and often branched in apical half; dorsal and ventral bundles of 6-12 spiracular hairs; lateral bundles of 4-6 hairs.

Anal area: lobes large with a lightly sculptured surface, surrounded by 3-7 rows of spinules. Around outer edges spinules small, in discontinuous rows; closer to anal lobes, spinules becoming stouter, and forming small groups below anal opening (CABI 2020, White and Elson-Harris 1994).

Pupa: Barrel-shaped with most larval features unrecognisable, the exception being the anterior and posterior spiracles which are little changed by pupariation. White to yellow-brown in colour. Usually about 60-80% length of larva (CABI 2020, White and Elson-Harris 1994).

Adult: Head: Pedicel+1st flagellomere not longer than ptilinal suture. Face with a dark spot in each antennal furrow; facial spot round to elongate. Frons 2-3 pairs frontal setae; 1 pair orbital setae.

Thorax: Predominant colour of scutum red-brown. Postpronotal (humeral) lobe entirely pale (yellow or orange). Notopleuron yellow. Scutum with parallel sided lateral postsutural vittae (yellow/orange stripes) which extend anterior to suture and posteriorly to level of the intra-alar setae. Medial vitta present; not extended anterior to suture. Scutellum yellow, except for narrow basal band. Anepisternal stripe not reaching anterior notopleural seta. Yellow marking on both anatergite and katatergite. Postpronotal lobe (humerus) without a seta. Notopleuron with anterior seta. Scutum with or without anterior supra-alar setae; with prescutellar acrostichal setae. Scutellum rarely (5%) with basal as well as apical pair of setae.

Wing: Length 4.2-7.1 mm. With a complete costal band; depth to below R2+3, sometimes reaching R4+5. Costal band expanded into a spot at apex, which extends about half way to M. With an anal streak. Cells bc and c colourless. May have a transverse mark over crossvein r-m. Always with transverse mark over crossvein dm-cu. Cells bc and c without extensive covering of microtrichia. Cell br (narrowed part) with extensive covering of microtrichia.

Legs: All femora pale basally, red-brown apically.

Abdomen: Predominant colour orange-brown. Tergites not fused. Abdomen not wasp waisted. Pattern distinct; transverse band across tergite 3; tergite 4 dark laterally; medial longitudinal stripe on T3-5.

Terminalia and secondary sexual characters: male wing without a bulla. Male tergite 3 with a pecten (setal comb) on each side. Male sternite 5 not V-shaped. Surstylus (male) with a long posterior lobe. Wing (male) with a deep indent in posterior margin. Hind tibia (male) with a preapical pad. Aculeus apex pointed (CABI 2020, White and Elson-Harris 1997).

2.4. Life cycle

The melon fruit fly remains active throughout the year on one or the other host. During the severe winter months, they hide and huddle together under dried leaves of bushes and trees. During the hot and dry season, the flies take shelter under humid and shady places and feed on honeydew of aphids infesting the fruit trees. The lower developmental threshold for melon fruit fly was recorded as 8.1°C (Keck 1951). The lower and upper developmental thresholds for eggs were 11.4 and 36.4°C (Messenger and Flitters 1958). The accumulative day degrees required for egg, larvae, and pre-egg laying adults were recorded as 21.2, 101.7, and 274.9 day degrees, respectively (Keck 1951). This species actively breeds when the temperature falls below 32.2°C and the relative humidity ranges between 60 to 70%. Fukai (1938) reported the survival of adults for a year at room temperature if fed on fruit juices. In general, its life cycle lasts from 21 to 179 days (Narayanan and Batra 1960; Fukai 1938). Development from egg to adult stage takes 13 days at 29°C in Solomon Islands (Hollingsworth *et al.* 1997). High temperature, long period of sunshine and plantation activity influences the *B. cucurbitae* abundance in the North-Eastern Taiwan (Lee *et al.* 1992). Bhatia and Mahto (1969) reported that the life cycle is completed in 36.3, 23.6, 11.2, and 12.5 days at 15, 20, 27.5 and 30°C, respectively. There are 8 to 10 generations in a year (Weems and Heppner 2001, White and Elson-Harris 1994).

2.5. Morphometric

Egg: Freshly laid eggs were glistening white, slightly curved, tapering at one end while rounded at the other end of melon fruit fly, *Bactrocera cucurbitae* (Coquillett). The mean length and breadth of the egg were found to be 1.13 ± 0.14 mm and 0.28 ± 0.05 mm (Mir *et al.* 2014, Lanjar *et al.* 2013, Shivayya *et al.* 2007,Dhillon*et al.* 2005).

The eggs of Bactrocera olae were described in detail by Margaritis (1985) and those of other species are probably very similar. Size, 0.8 mm long, 0.2 mm wide, with the micropyle protruding slightly at the anterior end. The chorion is reticulate. White to yellow-white in colour.

The eggs lay by *B. cucurbitae* inside the fruit, which are creamy, white in color; oblong; banana shaped and is about 1.3 mm in length (Anon 1987).

Larva: The first and second instars measured 1.49 ± 0.28 and 6.40 ± 0.86 mm in length, respectively, and 0.31 ± 0.07 and 1.21 ± 0.09 mm in breadth, respectively. The third instar was very mobile and measured 9.62 ± 0.87 mm in length and 2.05 ± 0.32 mm in breadth (Mir *et al.* 2014, Lanjar *et al.* 2013, Shivayya *et al.* 2007,Dhillon*et al.* 2005).

Pupa: The puparium measured 5.72 ± 0.13 mm in length and 2.46 ± 0.11 mm in breadth. The average length and breadth of pupae were observed 5-6 mm and 2.5-2.7 mm, respectively (Mir *et al.* 2014, Lanjar *et al.* 2013, Shivayya *et al.* 2007,Dhillon*et al.* 2005).

The pupa is cylindrical in shape and is 4-5 mm long and 2 mm broad. The color varies from dull deep reddish yellow to pale white (Rituraj 2011).

The puparium is 4.8 to 6.0 mm in length (Mitchell *et al.* 1965).

Adult: The length and breadth of male was 8.74 ± 0.32 mm and 11.46 ± 1.16 mm, whereas, the female measured 9.94 ± 0.20 mm in length and 15.92 ± 0.74 mm in breadth (Mir *et al.* 2014, Lanjar *et al.* 2013, Shivayya *et al.* 2007, Dhillon *et al.* 2005).

The adult fly (*B. cucurbitae*) is about 8 mm in body length; reddish brown in color with yellow stripes on its dorsal thorax and has brown spots along the veins otherwise clear wings (Anon 1987).

2.6. Biology

Mir *et al.* (2014) revealed that, 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. Longevity of adults was extended to 30-52 days for males and 30-60 days for females when fed either water, molasses and honey or water, molasses and proteinex.

2.6.1. Mating and Oviposition

Anonymous (1987) also reported mating of adult and female cucurbit fruit fly was occurred at about dusk and lasts for about one hour or more. According to Shivay *et al.* (2007) fruit flies mated during the night between 18:30 PM-01:30 AM. Adults begin to mate 9-12 days after emergence (Rituraj 2011).

The males of the *B. cucurbitae* mate with females for 10 or more hours, and sperm transfer increases with the increase in copulation time. Egg hatchability is not influenced by mating duration (Tsubaki and Sokei 1988). Yamagishi and Tsubaki (1990) observed that no sperms were transferred during the first 0.5 h of copulation. Sperm transfer increased to nearly 6400 until 4h, and thereafter, the number of sperms remained almost unchanged up to 8h of copulation. The pre-oviposition period of flies fed on cucumbers ranged between 11 to 12 days (Hollingsworth *et al.* 1997,Back and Pemberton 1917). Pre-oviposition and oviposition periods range between 10 to 16.3, and 5 to 15 days, respectively, and the females live longer (21.7 to 32.7 days) than the males (15.0 to 28.5 days) (Koul and Bhagat 1994).

Mating between the adult male and female cucurbit fruit flies generally takes place at about dusk and lasts for about an hour or more (Narayanan and Batra 1960). Studies on fruit fly mating behaviour revealed that most of flies in tropical and subtropical areas mate when light intensity decreases at dusk (Bateman 1979). Although some species belonging the genus Bactrocera prefer to mate in the morning and early afternoon (Alwood 1997).

The mean Pre-oviposition period 13.5±1.5 and oviposition period 18.0 ± 6 days while, mean mating period (3±1 hrs), fecundity 80.0± 20 eggs/life cycle and incubation period of eggs varied from 1.25±0.25 days was observed of cucurbit fruit fly (Sohrab *et al.* 2018).

The pre-mating and oviposition periods lasted for 4 to 7 days and 14 to 17 days, respectively (Vargas *et al.* 1992).

The durations of pre-oviposition and oviposition Periods of cucurbit fruit flies were observed on ridge gourd. Mir *et al.* (2014) and Lanjar *et al.* (2013) were fairly closed this experiment and who reported the respective range of preoviposition and oviposition (11 ± 0.62 and 19.29 ± 1.19) and 10-15 and 12-28 days respectively.

The pre-oviposition period of flies fed on cucumbers ranged between 11 to 12 days (Hollingsworth *et al.* 1997). Pre-oviposition and oviposition periods range between 10 to 16.3, and 5 to 15 days, respectively, and the females live longer (21.7 to 32.7 days) than the males (15.0 to 28.5 days) (Koul and Bhagat 1994).

The pre-mating and oviposition periods lasted for 4 to 7 days and 14 to 17 days, respectively. The females survived for 123 days on papaya in the laboratory (24°C, 50% RH and LD 12:12) (Vargas *et al.* 1992), while at 29°C they survived for 23.1 to 116.8 days (Vargas *et al.* 1997).

2.6.2. Incubation period

Narayanan and Batra (1960) *B. cucurbitae* eggs laid creamy white, oblong, bananas shaped and are about 1.3 mm in length. The posterior extremity was broadly rounded while the anterior end was appeared more pointed. The eggs were fixed vertically or slightly at an angle and touching each other. The eggs are laid singly or in clusters of into flowers or tender fruits.

The eggs hatch within 18 hours in summer and 3–4 days in winter. The egg incubation period on pumpkin, bitter gourd, and squash gourd has been reported to be 4.0 to 4.2 days at 27 ± 1°C (Doharey 1983), 1.1 to 1.8 days on bitter gourd, cucumber and sponge gourd (Gupta and Verma 1995), and 1.0 to 5.1 days on bitter gourd (Hollingsworth *et al.* 1997, Koul and Bhagat 1994).

Hatching percent eggs of fruit fly 87.5 ± 2.5 was observed in 2015 at average maximum and minimum temperature 34.36–25.46°C and average relative humidity 87.5% respectively during experiment in the month of June and July (Sohrab *et al.* 2018).

Lanjar *et al.* (2013) and Manzar and Srivastava (2007) were fairly close this experiment and who reported the respective range of incubation period of eggs of fruit fly were 1.4 ± 0.16 and 2.29 ± 0.18 days respectively.

The eggs were hatch out from eggs in 1-1.5 days feed on the pulp and seeds of fruit, drop to the ground (Sohrab *et al.* 2018).

2.6.3. Larval period

Soon after hatching the young larvae (maggots) bore into the flower buds or into the fruits and start feeding. The full-grown maggots measure 9–10 mm long and 2 mm broad across the thorax and are cream or pale white in colour. The full-grown larvae develop into barrel shaped, light brown or pale colour pupae in 0.5 to 3 inches deep in soil within 7–14 days. The pupae emerge into adults within 5- 8 days in summer and within about 3 weeks in winter.

The larval period lasts for 3 to 21 days (Hollingsworth *et al.* 1997, Narayanan and Batra 1960, Renjhan 1949), depending on temperature and the host. On different cucurbit species, the larval period varies from 3 to 6 days (Gupta and Verma 1995, Koul and Bhagat 1994, Doharey 1983, Chelliah 1970, Chawla 1966).

Fully developed maggot of fruit fly was white in color white grey color patches on body. The apodous maggot was passed through 3 instars. Mean of total maggot period was with a mean

5.18 ± 1.16 days (Sohrab *et al.* 2018).

Mir *et al.* (2014), Lanjar *et al.* (2013), Ullah *et al.* (2008), Manzar and Srivastava (2007) and Shivay *et al.* (2007) were fairly close this experiment and who reported the respective range of Maggots (larvae) period of cucurbit fruit fly were 5.9 ± 0.9, 12.25, 4.5-7.5, 7.00, 4-7, 8.94 ± 0.6, 4.5 ± 1.13 days respectively.

The eggs were hatch out from eggs in 1-1.5 days feed on the pulp and seeds of fruit, drop to the ground. Fully developed maggot of fruit fly was white in color white grey color patches on body. The apodous maggot was passed through 3 instars. Mean of total maggot period was with a mean 5.18 ± 1.16 days.

The creamy white maggot gradually becomes darker as it matures. The length of mature larvae is about 12 mm. The full grown larvae come out of the bores and make a loop holding the last abdominal segment by mouth hook and drop forcedly on the soil by releasing their mouth hook for pupation. This phenomenon takes place usually in the early morning between 6:00 am to 9:00 am. The most of the full grown larvae penetrate the soil rapidly and pupate under the soil surface. The larval period is 4-7 days, varying with temperature, nutritional condition, larval rearing density etc. (Anon. 1987).

The description of different stages of maggots is as follow:

First instar maggot: Freshly emerged first instars maggot was translucent and white in color. First instar maggots were taken the range of time 15-24 hrs and with a mean (0.81 ± 0.19) days for go to second instar maggot (Sohrab *et al.* 2018).

Second instar maggot: The second instar maggots were slightly different from the first instar maggots of fruit flies. There were larger sizes from the first instar maggots of fruit flies. The second instar maggots were translucent, elongate and ellipsoidal in shape and creamy white in color. The second instar maggots were taken average time of 1.5 ± 0.5 days to complete this stage and go to next instar maggot of fruit fly (Sohrab *et al.* 2018).

Third instar maggot: The fully grown third instars were a pointed head with well-developed mandibular hooks and anterior and posterior spiracles. The 3rd instar was a conspicuous dark transverse line extending between intermediate areas of the caudal segment and exhibited a peculiar habit of curving itself and springing into the air to a lateral distance of 15-20 cm by the sudden relaxation of certain muscles. In this way, the 3rd instar was displaced itself 6 to 8 inches (15-20 cm) from the fruit to the site of pupation. The second 3rd instars maggot were taken average time of 3.0 ± 0.5 days to complete this stage (Sohrab *et al.* 2018).

2.6.4. Pupal period

Pre-pupal period and pupal period was 0.75 ± 0.25 and 9.5 ± 0.5 days respectively during experiment in the month of June and July (Sohrab *et al.* 2018).

The full-grown larvae come out of the fruit by making one or two exit holes for pupation in the soil. The larvae pupate in the soil at a depth of 0.5 to 15 cm. The depth up to which the larvae

move in the soil for pupation, and survival depend on soil texture and moisture (Pandey and Misra 1999, Jackson *et al.* 1998).

Doharey (1983) observed that the pupal period lasts for 7 days on bitter gourd and 7.2 days on pumpkin and squash gourd at 27 ± 1°C. In general, the pupal period lasts for 6 to 9 days during the rainy season, and 15 days during the winter (Narayanan and Batra 1960). Depending on temperature and the host, the pupal period may vary from 7 to 13 days (Hollingsworth *et al.* 1997). On different hosts, the pupal period varies from 7.7 to 9.4 days on bitter gourd, cucumber, and sponge gourd (Gupta and Verma 1995), and 6.5 to 21.8 days on bottle gourd (Koul and Bhagat 1994, Khan *et al.* 1993).

The duration of pupal stage varied 9 to 10 days with a mean of 9.5 ± 0.5 days, respectively. Mir *et al.* (2014), Lanjar *et al.* (2013), Ullah *et al.* (2008),Manzar and Srivastava (2007) and Shivay *et al.* (2007) were fairly close and differ this experiment result and who reported the respective range of pupal period of cucurbit fruit fly were 7.3 ± 0.23, 7.75, 7.00-711.50, 8.33, 9, 9.94 ± 1.03 and 8.4 ± 0.51 days respectively at different hosts, time, weather conditions and etc.

The pupal stage lasts for 8-12 days at 23-25°C and 9 days at 27°C (Rituraj 2011). At the 23-25^{o}C, the pupal stage lasts for 8-12 days. At 27°C, the mean pupal period for *B. dorsalis* and *Ceratitis capitata* (Wiedcmann) is 10 days and that for *B. cucurbitae* is 9 days (Mitchell *et al.* 1965).

Pupation formation may require as little as one hour and complete within the puparium by less than 48 hours (Christenson and Foote 1960). The larvae spend 4th instar in the puparium formed by the exuviae of the 3rd instar and subsequently become pupae (Mitchell *et al.* 1965).

2.6.5. Adult longevity

The fruit fly adults are free living, reddish brown with lemon yellow in colour, having curved vertical markings and fuscous shading on the outer margin of the wings.

The average longevity of adult fruit flies were neither food nor water immediately, die after range of 1.5 ± 0.5 days after emergence from pupa. When was provided with cucurbit vegetables materials to fruit flies then fruit flies were lived 13.5 ± 1.5 days. The duration of total life cycle was 16.81 ± 2.18 days during 2015 in June and July under room temperature in meerut condition (Sohrab *et al.* 2018).

The adults survive for 27.5, 30.71 and 30.66 days at 27 ± 1°C on pumpkin, squash gourd and bitter gourd, respectively (Doharey, 1983). Khan *et al.* (1993) reported that the males and females survived for 65 to 249 days and 27.5 to 133.5 days respectively.

The females survived for 123 days on papaya in the laboratory (24°C, 50% RH and LD 12: 12) (Vargas *et al.* 1992), while at 29°C they survived for 23.1 to 116.8 days (Vargas *et al.* 1997).

The longevity of adults was extended up to 2-3 and 3-4 days by access to water only. When was provided with cucurbit vegetables materials then fruit flies were lived 12-15 days. Mir *et al.* (2014), Lanjar *et al.* (2013), Ullah *et al.* (2008), Manzar and Srivastava (2007) and Shivay *et al.* (2007) were fairly closed and differed this experiment and who reported the respective range of adult longevity of cucurbit fruit fly were 13.09 ± 2.7, 18.4 ± 0.64, 26.00, 37.86 ± 1.40 and 30-52 days respectively at different hosts, time, temperature and weather conditions.

2.6.6. Total life cycle

One generation takes around 37 days; egg to adult in 15–18 d; eggs hatch in about 30 hr; larvae develop in 7–8 d; adults emerge in 9–10 d; pre-oviposition period is 7–8 d; females lay an average of 15 eggs /day, singly or in clusters (Messing 1999).

According to Janjua (1948), the pre-oviposition period of *D. (Strumeta) ferrugeneus* is two to five days but it may range from ten to fifteen days or longer in varying conditions of climate and diet. In another report of Butani and Jotwani (1984) indicates that the pre-oviposition periods of melon fly lasts for 9-12 days. A single life cycle is completed in 10 to 18 days but it takes 12 to 13 weeks in winter. Adult longevity is 2 to 5 months; females live longer than males. Generally, males die soon after fertilizing the females, whereas, females die after completing egg lying. Nair (1986) reported that the flies, which emerge in the morning hours, oviposit for four days in autumn and nine to thirty days in winter. Adults begin to copulate 9-12 days after emergence and the longevity of adult fly is one to five months in the laboratory and under the optimum condition, the length of one generation is around one month (Anon 1987).

Bhatia and Mahto (1969) reported that the life cycle is completed in 36.3, 23.6, 11.2, and 12.5 days at 15, 20, 27.5, and 30°C, respectively. Egg viability and larval and pupal survival on cucumber have been reported to be 91.7, 86.3, and 81.4%, respectively; while on pumpkin these were 85.4, 80.9, and 73.0%, respectively, at 27 ± 1°C (Samalo *et al.* 1991). High temperatures, long period of sunshine and plantation activates influence the *B. cucurbitae* abundance in the Northeastern Taiwan (Lee *et al.* 1992). Development from egg to adult stage takes 13 days at 29°C in Solomon Islands (Hollingsworth *et al.* 1997). There are 8 to 10 generations in a year (Weems and Heppner 2001 and White and Elson-Harris 1994).

The life cycle from egg to adult takes between 14 and 27 days. The duration of each stage and degree of survival depends on species, host plant and environmental conditions (Shaw *et al.* 1967).

2.6.7. Fecundity

Egg viability and larval and pupal survival on cucumber have been reported to be 91.7, 86.3, and 81.4%, respectively; while on pumpkin these were 85.4, 80.9, and 73.0%, respectively, at 27 ± 1°C (Samalo *et al.* 1991).

Mean single generation time is 71.7 days, net reproductive rate 80.8 births per female, and the intrinsic rate of increase is 0.06 times (Vergas *et al.* 1992). Yang *et al.* (1994) reported the net reproductive rate to be 72.9 births per female.

Bactrocera cucurbitae strains were selected for longer developmental period and larger body size on the basis of pre-oviposition period, female age at peak fecundity, numbers of eggs at peak fecundity, total fecundity, longevity of males and females, age at first mating, and number of life time matings (Miyatake 1995). However, longer developmental period was not necessarily associated with greater fecundity and longevity (Miyatake 1996). The peak larval, pre-oviposition, and oviposition periods were observed to be 6.48 versus 6.89, 14.0 versus 20.0, and 32 versus 62 days, respectively after nine and 24 generations of mass rearing and selection under laboratory conditions (Miyatake 1997 & 1998a). The egg hatchability and larval-pupal survival were 81.3 versus 89%, and 75.8 versus 77.2% after nine and 24 generations of mass rearing and selection. Miyatake (1998b) reported that males show heritable variation in pre-mating period, while no such effects were observed in the females. The population of *B. cucurbitae* mass reared for a long time has a shorter pre-mating period than the population reared for short-term. A genetic trade-off has been observed between early-fecundity and longevity. The mass reared population has a negative genetic correlation between early-fecundity and longevity indicating antagonistic pleiotropy. The selected strain had lower and early fecundity than the non-selected strain (Miyatake 1997, Kakinohana and Yamagishi 1991, Kamikado *et al.* 1987, Soemori and Nakamori 1981). Therefore, it may be interesting to examine the mating ability of the males of

the selected strain, because the effectiveness of the sterile-male release technique depends on the mating ability of the sterile males released into the eco-system. The genetic trade-off between behavioral traits should be taken into account along with life history during mass rearing programs, which might result in significant pre-mating isolation in the melon fly populations (Miyatake and Shimizu 1999, Miyatake 1998a).

The adult female lay eggs usually just below the epidermis of the fruits by inserting their ovipositor. The eggs are laid singly or in clusters of 4 to 10. A single adult can lay 42 to 58 eggs.

Laskar (2013) and Shivayy *et al.* (2007) has been reported fruit fly 188-250 and 138 ± 44.05 eggs laid in entire life span. Lanjar *et al.* (2013) also reported 50-91 eggs of the melon fly per female during her entire life span under laboratory conditions.

Yang *et al.* (1994) reported the net reproductive rate to be 72.9 births per female.

Egg viability and larval and pupal survival on cucumber have been reported to be 91.7, 86.3, and 81.4%, respectively; while on pumpkin these were 85.4, 80.9, and 73.0%, respectively, at 27 ± 1°C (Samalo *et al.* 1991).

Mean single generation time is 71.7 days, net reproductive rate 80.8 births per female, and the intrinsic rate of increase is 0.06 times (Vergas *et al.* 1992). Adults were provided neither food nor water immediately; die after range of 1 to 2 days after emergence from pupa.

2.7. Sex ratio

Newly emerged adults were critically examined and sexed by the presence or absence of a pointed ovipositor. The sex ratio was 1.10 ± 0.14 (mean ± SD), which varied from 0.95-1.25 (male: female) (Mir *et al.* 2014).

Laskar (2013) reported that the sex ratio of *B. cucurbitae* varied from 1.102 ± 0.136 on bitter gourd (*Momordica charantia* L.) and 0.976 ± 0.104 on pumpkin (*Cucurbita pepo* L.).

2.8. Host preference

B. cucurbitae is a very serious pest of cucurbit crops. According to Weems (1964), it has been recorded from over 125 plants, including members of families other than Cucurbitaceae; however, many of those records were based on casual observation of adults resting on plants or caught in traps set in non-host trees. In common with some other species of subgenus *Bactrocera* (*Zeugodacus*) it can attack flowers as well as fruit, and additionally, will sometimes attack stem and root tissue. In Hawaii, pumpkin and squash fields have been known to be heavily attacked before fruit had even set, with eggs being laid into unopened male and female flowers, and larvae even developing successfully in the taproots, stems and leaf stalks (Back and Pemberton 1914).

2.8.1. Primary host

Primary hosts are species of Cucurbitacaeae, as follows: *Cucumis melo* (Allwood *et al.* 2000, Drew 1989), *Cucurbita maxima* (Allwood *et al.* 2000, Tsuruta *et al.* 1997), *Cucurbita pepo* (Allwood *et al.* 2000, Drew 1989) and *Trichosanthes cucumerina* (Allwood *et al.* 2000, Tsuruta *et al.* 1997).

2.8.2. Secondary host

Secondary hosts are species of Cucurbitaceae and rarely species of other families, as follows:

Cucurbitaceae:*Benincasa hispida* (Allwood *et al.* 2000) fruit and flowers, *Citrullus colocynthis* (White and Elson-Harris 1994), *Citrullus lanatus* (Allwood *et al.* 2000), *Coccinia grandis* (Allwood *et al.* 2000, Tsuruta *et al.* 1997) fruit and flowers, *Cucumis anguria* (Ravi *et al.* 1998),

Cucumis sativus (Allwood *et al.* 2000,Tsuruta *et al.* 1997, Drew 1989), *Cucurbita moschata* (Allwood *et al.* 2000) fruit and flowers, *Lagenaria siceraria* (Allwood *et al.* 2000, Tsuruta *et al.* 1997), *Luffa acutangula* (Allwood *et al.* 2000, Tsuruta *et al.* 1997), *Luffa aegyptiaca* (Allwood *et al.* 2000) fruit and flowers, *Momordica balsamina* (White and Elson-Harris 1994), *Momordica charantia* (Allwood *et al.* 2000, Tsuruta *et al.* 1997, Drew 1989), *Momordica cochinchinensis* (White and Elson-Harris 1994) and *Momordica dioica* (Ranganath and Veenakumari 1995).

Caricaceae:*Carica papaya* (Tsuruta *et al.* 1997);

Fabaceae:*Phaseolus vulgaris*, *Vigna sinensis* and *Vigna unguiculata* (Allwood *et al.* 2000);

Loganiaceae:*Strychnos nux-vomica* (Tsuruta *et al.* 1997);

Malvaceae:*Abelmoschus moschatus* (Allwood *et al.* 2000);

Myrtaceae:*Psidium guajava* (Allwood *et al.* 2000);

Pandanaceae:*Pandanus odoratissimus* [*Pandanus odorifer*] (Tsuruta *et al.* 1997);

Passifloraceae:*Passiflora edulis* (Tsuruta *et al.* 1997);

Rhamnaceae:*Ziziphus jujuba* (Allwood *et al.* 2000);

Sapotaceae:*Manilkara zapota* (Allwood *et al.* 2000);

Solanaceae:*Lycopersicon esculentum* (Allwood *et al.* 2000).

2.8.3. Wild host

Wild hosts of *B. cucurbitae* are wild species of Cucurbitaceae and rarely fruits of other families, as follows:

Cucurbitaceae:*Cucumis trigonus* (White and Elson-Harris 1994), *Diplocyclos palmatus* (Tsuruta *et al.* 1997), *Gymnopetalum integrifolium* (Allwood *et al.* 2000), *Melothria wallichii* (Allwood *et al.* 2000), *Mukia maderaspatana* [*Cucumis maderaspatanus*] (Ranganath and

Veenakumari 1995), *Trichosanthes ovigera*, *Trichosanthes tricuspidata*, *Trichosanthes wallichiana* and *Trichosanthes wawraei* (Allwood *et al.* 2000).

Agavaceae:*Dracaena curtissi* (Allwood *et al.* 2000);

Capparidaceae:*Capparis sepiaria*, *Capparis thorellii* and *Maerua siamensis* (Allwood *et al.* 2000);

Moraceae:*Ficus chartacea* (Allwood *et al.* 2000);

Rutaceae:*Citrus hystrix* (Allwood *et al.* 2000);

Solanaceae:*Solanum trilobatum* (Allwood *et al.* 2000);

Vitaceae:*Tetrastigma lanceolarium* (Allwood *et al.* 2000).

Batra (1953) listed as many as 70 hosts of fruit fly species, whereas, Christenson and Foote (1960) reported more than 80 kinds of fruits and vegetables as the hosts. Kapoor (1993) reported that more than one hundred vegetables and fruits are attacked by Bactrocera sp. Atwal (1993) and Micknlay (1992) reported that cucurbits as well as 70-100 non-cucurbitaceous vegetables and fruits are the host of fruit fly. Tomato, green pepper, papaya, cauliflower, mango, guava, citrus, pear, fig and peaches were also infested by fruit fly (Atwal 1993 and Anon. 1987). In Bangladesh, Alam (1962) reported ten cucurbit vegetables as the host of fruit fly. Kabir *et al.* (1991) found that 16 species of plants act as the host of fruit flies among which sweet gourd was the most preffered host of both *B. cucurbitae* and *B. tau*.

Host preference for oviposition was determined by incubating fruits and vegetables to natural infestations by *Bactrocera* in the field, and their larvae reared and adults maintained in the laboratory. Comparative host preference of the *B. zonata* fruit fly was studied on mango, peach and apple fruits in field experiments. The mango was recorded as most preferred host followed by peach and apple, due to the maximum number of pupae formed (173.17) of fruit fly. The

vegetables, bitter gourd, brinjal, muskmelon and pumpkin were tested for the relative host preference of fruit fly *B. cucurbitae*. The bitter gourd was found as most preferred host demonstrating the maximum pupae formation (134.08) of fruit fly. Brinjal was observed as moderately preferred host, while, muskmelon and pumpkin were sorted out as least preferred hosts (Sarwar *et al.* 2013).

Melon fruit fly damages over 81 plant species. Based on the extensive surveys carried out in Asia and Hawaii, plants belonging to the family Cucurbitaceae are preferred most (Allwood *et al.* 1999).

Doharey (1983) reported that it infests over 70 host plants, amongst which, fruits of bitter gourd (*Momordica charantia*), muskmelon (*Cucumis melo*), snap melon (*Cucumis melo var. momordica*) and snake gourd (*Trichosanthes asguinam* and *T. cucumeria*) are the most preferred hosts. However, White and Harris (1994) stated that many of the host records might be based on casual observations of adults resting on plants or caught in traps set in non-host plant species. In the Hawaiian Islands, melon fruit fly has been observed feeding on the flowers of the sunflower, Chinease bananas and the juice exuding from sweet corn.

Under induced oviposition, McBride and Tanda (1949) reported that broccoli (*Brassica oleraceavar. capitata*) tangerine (*Citrus reticulata*) and longan (*Euphoria longan*) are doubtful hosts of *B. cucurbitae*. The melon fly has a mutually beneficial association with the Orchid, Bulbophyllum patens which produce zingerone.

Fruit flies are serious pests in Pakistan, causing losses at the farm level, and with added losses to traders, retailers and exporters. Small farmers suffer in particular, being the growers of the highly

susceptible items and unable to afford enough protection measures. Losses without control have been estimated as 21% of fruits and 24% of cucurbits in Pakistan (Stonehouse *et al.* 1998).

Muthuthantri and Clarke (2012) investigated oviposition preference and offspring performance of the polyphagous fruit fly *Bactrocera tryoni* (Froggatt) in citrus as host based on choice and no-choice experiments in laboratory studies. These findings demonstrated an oviposition preference hierarchy of *B. tryoni* among the citrus fruits host tested.

The maximum numbers of 134.08 pupae formed were recovered from the *B. cucurbitae* flies fed on bitter gourd diet followed by 8.25, 3.83 and 3.83 pupae in case of brinjal, muskmelon and pumpkin, respectively (Sarwar *et al.* 2013).

B. cucurbitae might utilize four vegetable hosts depending upon their availability; however, the quality of host came out to have a key role on progeny development of particular species of fly concerned. Hence, host species and quality both affect adult behavior as well as immature instars development of fruit fly (Sarwar *et al.* 2013).

More than 150 species of plants, including cucurbits, tomatoes, and many other vegetables have been recorded as hosts of the melon fly. Preferred hosts include cantaloupe, water melon, pumpkin, squash, gourd, cucumber, tomato, string bean and cowpea (Mandal 2015).

Rajpoot *et al.* (2002), tested cucurbits for the relative population and host preference of fruit fly and categorized those as most preferred, moderately preferred and least preferred hosts.

Fitt (1986) also noted that the abundance of species on different hosts was due to more the choices made by females than to larval specialization. However, while many host plants can sustain the full development of different tephritid species, host quality can manage most important differences in survival rate and larval specialization.

The relationship between host preference and the offspring performance measures showed strong support for the preference- performance hypothesis, which stated that female insects will evolve to oviposit on hosts on which their offspring fare best (Akol *et al.* 2013).

Taste becomes important only after the fly makes physical contact with food. A fly first locates food sources using its odor receptors which are crucial for its long-range attraction to food. Then, after landing on food, the fly uses its taste system to sample the food for suitability in terms of nutrition and toxicity (Wisotsky *et al.* 2011).

Adult female fruit flies find and assess larval hosts using olfactory, visual and contact cues such as the color, size, shape and smell of host fruit, and all these factors influence a female fruit fly's response (Mahfuza *et al.* 2011, Brevault and Quilici 2007, Drew *et al.* 2003).

Flies have adapted behaviorally to the phenology of host plants. However, adaptations to different host-plant phenologies and host plant physiology may be required (Feder *et al.* 1997).

Plants that differ in the amount of secondary metabolites (Roitberg and Isman 1992) and nutritional value can result in reduced growth and survival of the feeding larvae (Haggstrom and Larsson 1995).

The most favorite host to *B. cucurbitae* fly was bitter gourd followed by brinjal, muskmelon and finally pumpkin (Feng-Ming 1997).

Occasional hosts include oil-seed, vegetables such as eggplant, orange, papaya, mango, peach, fig, guava, loquat, plum peach, pear, fig, apple, quince, persimon, banana, pomegranate, jujube, tomato, sweet lime, chillies, jackfruit, carambola, papaya, avocado, bread fruit, coffees, berries, passion fruit, star apple, Spanish pepper, cherries, blackberry, cape gooseberry, grapes, mulberry etc. Wild hosts include passion-flower, *Passiflora* sp.; balsam apple, *Diplocyclos palmatus*;

colocynth, *Cucumis trigonus*; and two gerera of cucurbits *Sicyos* sp. and *Chinese cucumber*, *Momordica* spp. Melon flies have more than 80 hosts. They are major pests of beans, bittermelon, Chinese wax gourd, cucumbers, edible gourds, eggplant, green beans, hyotan, luffa, melons, peppers, pumpkins, squashes, togan, tomatoes, watermelon and zucchini (Weems and Hoppner 2001).

B. cucurbitae emerging from cashew fruit (*Anacardium occidentale*), which makes this species a completely new host plant for the melon fly. Other than this mango, orange, carmbola, tomato, passion fruit etc. are the host for the fruit fly (Vayssieres *et al.* 2007, Dhillon *et al.* 2005, White and Elson-Harris 1992, Harris *et al.* 1986).

Drew *et al.* (2005) listed four cultivated host plants, namely, guava, mango, citrus, papaya, and some unidentified wild plants as host of *B. invadens* in Africa. In Benin, West Africa, Vayssieres *et al.* (2005) reported attacks on cashew (*Anacardium occidentale* L.), pepper (*Capsicum annuum* L.), *Cucurbita* spp., custard apple, guava, mango, papaya, *Diospyros montana* Roxburgh (Ebenaceae), and *Vitellaria paradoxa* C.F. Gaertner (Sapotaceae) by genus *Bactrocera*.

In Tanzania, Mwatawala *et al.* (2006) reported 15 host plants and identified mango, loquat (*Eriobotrya japonica*), guava, and grapefruit (*Citrus xparadisi*) as the favored hosts.

B. invadens was found to infest fruit species within the families Annonaceae, Rutaceae, Boraginaceae, Solanaceae, Anacardiaceae, Musaceae, Myrtaceae, and Combretaceae, suggesting that *B. invadens* is an emerging polyphagous pest that may be capable of sustaining its population through reproduction on a range of cultivated and wild fruit (Rwomushana *et al.* 2008).

2.9. Dispersal of fruit fly

The first *B. cucurbitae* specimens from Africa are from the early 1930s, but it is possible that the fly has been established on the continent for much longer. It was restricted to eastern Africa for several decades, but has recently been reported from western Africa and the Seychelles (Meyer *et al*. 2007).

B. cucurbitae was first found in Hawaii in the 1890s (Meyer *et al*. 2007).

In November 1999, *B. cucurbitae* was detected for the first time in the Seychelles. It is believed that the flies came from infested fruits and vegetables from a meal served on a plane, and the waste was not correctly treated at the airport. *B. cucurbitae* established quickly on Mahe Island and then invaded the other islands of the archipelago. An eradication programme was planned for 2004 after delimitation of the infestation (Knight 2003).

2.10. Damage assessment

Damage symptoms: Eggs are normally inserted under the skin of the fruits, vegetables, nuts or fleshy parts of plants, stems or flowers where they are protected from sun. The maggots feed inside just after hatching from the eggs (Feron *et al.* 1958).

Females lay their eggs mostly on soft fruit tissue (fruit in formation) and produce necrotic areas (brown dots) over the surface of the fruit and as a result the marketability of the product is reduced. Immature feed inside the fruits (although sometimes they can move to feed in other plant structures such as flowers or the stems), bore into the pulp tissue and make their feeding galleries, as a result fruits rot or becomes distorted. Normally, early instar larvae leave the necrotic areas of the fruit and move to healthy tissue expanding the damage and at the same time introducing various pathogens and hastening fruit decomposition (Dhillon *et al*. 2005).

It prefers young, green, and tender fruits for egg laying. The females lay the eggs 2 to 4 mm deep in the fruit pulp, and the maggots feed inside the developing fruits. At times, the eggs are also

laid in the corolla of the flower, and the maggots feed on the flowers. A few maggots have also been observed to feed on the stems (Narayanan 1953). The fruits attacked in early stages fail to develop properly, and drop or rot on the plant. Since, the maggots damage the fruits internally, it is difficult to control this pest with insecticides. Therefore, there is a need to explore alternative methods of control, and develop an integrated control strategy for effective management of this pest. The available information on the melon fruit fly has been reviewed in this manuscript to explore the possibilities for successful management of this pest in cucurbits.

Economic loss: Fruit flies can cause 30-100% economic losses annually in various crops such as gourds, melons and summer guavas (DFID 2005).

The majority of these fruit fly species pose a serious economic threat to agriculture due to the direct damage done to commercial horticulture (Yong *et al*. 2010). These losses can approach 100% in cucurbit species due to the melon fly, *B. cucurbitae* (Dhillon *et al*. 2005), on mango (12-60%), papaya (12-60%) and guava (40-90%) (Allwood *et al*. 1999).

Depending on the environmental conditions and susceptibility of the crop species, the extent of losses varies between 30 to 100% (Gupta and Verma 1992; Dhillon *et al*. 2005a, b, c; Shooker *et al*. 2006). The field experiments on assessment of losses caused by cucurbit fruit fly in different cucurbits been reported 28.7-59.2, 24.7-40.0, 27.3-49.3, 19.4-22.1 and 0-26.2% yield losses in pumpkin, bitter gourd, bottle gourd, cucumber, and sponge gourd, respectively, in Nepal (Pradhan 1976). Considering previous facts and reports, it is apparent that >50% of the cucurbits are either partially or totally damaged by fruit flies and are unsuitable for human consumption (Sapkota *et al.* 2010).

Maggots feed inside the fruits, but at times, also feed on flowers, and stems. Generally, the females prefer to lay the eggs in soft tender fruit tissues by piercing them with the ovipositor. A

watery fluid oozes from the puncture, which becomes slightly concave with seepage of fluid, and transforms into a brown resinous deposit. Sometimes pseudo-punctures (punctures without eggs) have also been observed on the fruit skin. This reduces the market value of the produce. In Hawaii, pumpkin and squash are heavily damaged even before fruit set. The eggs are laid into unopened flowers, and the larvae successfully develop in the taproots, stems, and leaf stalks (Weems and Heppner 2001). Miyatake *et al.* (1993) reported <1% damage by pseudo-punctures by the sterile females in cucumber, sponge gourd and bitter gourd. After egg hatching, the maggots bore into the pulp tissue and make the feeding galleries. The fruit subsequently rots or becomes distorted. Young larvae leave the necrotic region and move to healthy tissue, where they often introduce various pathogens and hasten fruit decomposition. The vinegar fly, Drosophilla melanogaster has also been observed to lay eggs on the fruits infested by melon fly, and acts as a scavenger (Dhillon *et al.* 2005b). The extent of losses vary between 30 to 100%, depending on the cucurbit species and the season. Fruit infestation by melon fruit fly in bitter gourd has been reported to vary from 41 to 89% (Lall and Sinha 1959; Narayanan and Batra 1960; Kushwaha *et al*. 1973; Gupta and Verma 1978; Rabindranath and Pillai (1986). The melon fruit flyhas been reported to infest 95% of bitter gourd fruits in Papua (New Guinea), and 90% snake gourd and 60 to 87% pumpkin fruits in Solomon Islands (Hollingsworth *et al*. 1997). Singh *et al*. (2000) reported 31.27% damage on bitter gourd and 28.55% on watermelon in India. Fruit infestation by melon fruit fly in bitter gourd has been reported to vary from 41% to 89% (Lall and Sinha 1959), 90% snake gourd and 60% to 87% was gourd in Solomon Island. Like any other cucurbit crops, bitter gourd, snake gourd and wax gourd are severely affected by melon fruit fly.

2.11. Environmental effect

The melon fruit fly remains active throughout the year on one or the other host. During the severe winter months, they hide and huddle together under dried leaves of bushes and trees. During the hot and dry season, the flies take shelter under humid and shady places and feed on honeydew of aphids infesting the fruit trees. The lower developmental threshold for melon fruit fly was recorded as 8.1°C (Keck 1951). The lower and upper developmental thresholds for eggs were 11.4 and 36.4°C (Messenger and Flitters 1958). The accumulative day degrees required for egg, larvae, and pre-egg laying adults were recorded as 21.2, 101.7, and 274.9 day degrees, respectively (Keck 1951). This species actively breeds when the temperature falls below 32.2°C and the relative humidity ranges between 60 to 70%. Fukai (1938) reported the survival of adults for a year at room temperature if fed on fruit juices. In general, its life cycle lasts from 21 to 179 days (Narayanan and Batra 1960, Fukai 1938). Development from egg to adult stage takes 13 days at 29°C in Solomon Islands (Hollingsworth *et al*. 1997). High temperature, long period of sunshine, and plantation activity influence the *B. cucurbitae* abundance in the North-eastern Taiwan (Lee *et al*. 1992). Bhatia and Mahto (1969) reported that the life cycle is completed in 36.3, 23.6, 11.2, and 12.5 days at 15, 20, 27.5, and 30°C, respectively. There are 8 to 10 generations in a year (Weems and Heppner 2001, White and Elson-Harris 1994).

The egg incubation period on pumpkin, bitter gourd, and squash gourd has been reported to be 4.0 to 4.2 days at 27 ± 1°C (Doharey 1983), 1.1 to 1.8 days on bitter gourd, cucumber and sponge gourd (Gupta and Verma 1995), and 1.0 to 5.1 days on bitter gourd (Hollingsworth *et al*. 1997, Koul and Bhagat 1994). The larval period lasts for 3 to 21 days (Hollingsworth *et al*. 1997, Narayanan and Batra 1960, Renjhan 1949), depending on temperature and the host. On different cucurbit species, the larval period varies from 3 to 6 days (Gupta and Verma 1995, Koul and Bhagat 1994, Doharey 1983, Chelliah 1970, Chawla 1966). Egg viability and larval and pupal

survival on cucumber have been reported to be 91.7, 86.3, and 81.4%, respectively; while on pumpkin these were 85.4, 80.9, and 73.0%, respectively, at 27 ± 1°C (Samalo *et al*. 1991).

The full-grown larvae come out of the fruit by making one or two exit holes for pupation in the soil. The larvae pupate in the soil at a depth of 0.5 to 15 cm. The depth up to which the larvae move in the soil for pupation, and survival depend on soil texture and moisture (Pandey and Misra 1999, Jackson *et al*. 1998). Doharey (1983) observed that the pupal period lasts for 7 days on bitter gourd and 7.2 days on pumpkin and squash gourd at 27 ± 1°C. In general, the pupal period lasts for 6 to 9 days during the rainy season, and 15 days during the winter (Narayanan and Batra 1960). Depending on temperature and the host, the pupal period may vary from 7 to 13 days (Hollingsworth *et al*. 1997).

On different hosts, the pupal period varies from 7.7 to 9.4 days on bitter gourd, cucumber, and sponge gourd (Gupta and Verma 1995), and 6.5 to 21.8 days on bottle gourd (Koul and Bhagat 1994, Khan *et al*. 1993).

The males of the *B. cucurbitae* mate with females for 10 or more hours, and sperm transfer increases with the increase in copulation time. Egg hatchability is not influenced by mating duration (Tsubaki and Sokei 1988). Yamagishi and Tsubaki (1990) observed that no sperms were transferred during the first 0.5 h of copulation. Sperm transfer increased to nearly 6400 until 4 h, and thereafter, the number of sperms remained almost unchanged up to 8 h of copulation. The pre-oviposition period of flies fed on cucumbers ranged between 11 to 12 days (Hollingsworth *et al.* 1997, Back and Pemberton 1917). Pre-oviposition and oviposition periods range between 10 to 16.3, and 5 to 15 days, respectively, and the females live longer (21.7 to 32.7 days) than the males (15.0 to 28.5 days) (Koul and Bhagat 1994). The adults survive for 27.5,

30.71 and 30.66 days at 27 ± 1°C on pumpkin, squash gourd and bitter gourd, respectively (Doharey, 1983). Khan *et al*. (1993) reported that the males and females survived for 65 to 249 days and 27.5 to 133.5 days respectively. The pre-mating and oviposition periods lasted for 4 to 7 days and 14 to 17 days, respectively. The females survived for 123 days on papaya in the laboratory (24°C, 50% RH and LD 12:12) (Vargas *et al*. 1992), while at 29°C they survived for 23.1 to 116.8 days (Vargas *et al*. 1997). Mean single generation time is 71.7 days, net reproductive rate 80.8 births per female, and the intrinsic rate of increase is 0.06 times (Vergas *et al*. 1992). Yang *et al*. (1994) reported the net reproductive rate to be 72.9 births per female.

Bactrocera cucurbitae strains were selected for longer developmental period and larger body size on the basis of pre-oviposition period, female age at peak fecundity, numbers of eggs at peak fecundity, total fecundity, longevity of males and females, age at first mating, and number of life time matings (Miyatake 1995). However, longer developmental period was not necessarily associated with greater fecundity and longevity (Miyatake 1996). The peak larval, pre-oviposition, and oviposition periods were observed to be 6.48 versus 6.89, 14.0 versus 20.0, and 32 versus 62 days, respectively after nine and 24 generations of mass rearing and selection under laboratory conditions (Miyatake 1998a, 1997). The egg hatchability and larval-pupal survival were 81.3 versus 89%, and 75.8 versus 77.2% after nine and 24 generations of mass rearing and selection. Miyatake (1998b) reported that males show heritable variation in pre-mating period, while no such effects were observed in the females. The population of *B. cucurbitae* mass reared for a long time has a shorter pre-mating period than the population reared for short-term. A genetic trade-off has been observed between early-fecundity and longevity. The mass reared population has a negative genetic correlation between early-fecundity and longevity indicating antagonistic pleiotropy. The selected strain had lower and early fecundity than the non-selected

strain (Miyatake 1997, Kakinohana and Yamagishi 1991, Kamikado *et al*. 1987, Soemori and Nakamori 1981). Therefore, it may be interesting to examine the mating ability of the males of the selected strain, because the effectiveness of the sterile-male release technique depends on the mating ability of the sterile males released into the eco-system. The genetic trade-off between behavioral traits should be taken into account along with life history during mass rearing programs, which might result in significant pre-mating isolation in the melon fly populations (Miyatake and Shimizu 1999, Miyatake 1998a).

2.12. Management practices against cucurbit fruit fly

Cucurbit fruit fly is the major pest causes considerable economic damage of bitter gourd. It is important to manage or control the pest before its outbreak. Usually farmers try to control this pest using chemical insecticides but they failed because the larvae live in the internal portion of fruits. And they do not consider economic injury level that is hazardous to the environment. So, the judicious use of pesticide with bio-pesticide is important in the management of cucurbit fruit fly and it will be helpful in minimizing environmental hazard. Fruit fly infestation was reduced by 53 to 73 percent and yields were raised 1.4 to 2.3 times using the traps (IPM CRSP Annual Highlights 2002-2003). Bait spray (Steiner *et al.* 1988), trapping with chemical attractant (Qureshi *et al.* 1981) were undertaken to control fruit fly on various crops. Different types of attractants (Tanaka *et al.* 1978), cucurbit fruit fly traps (Nasiruddin and Karim 1992) and repellants of plant extracts (Sing and Srivastava 1985) were utilized against this pest with variable success.

2.12.1. Resistant cultivars against cucurbit fruit fly

Host plant resistance is an important component in integrated pest management programs. It does not cause any adverse effects to the environment and no extra cost is incurred to the farmers. Unfortunately success in developing high yielding and fruit fly-resistant varieties has been limited. There is a distinct possibility of transferring resistance genes in the cultivated genotypes from the wild relatives of cucurbits for developing varieties resistant to melon fruit fly through wide hybridization (Dhillon *et al*. 2005a).

Table 2.2. Sources of resistance to melon fruit fly

Crop	Genotypes	Remarks	Reference
Bitter gourd	IHR 89 and IHR 213	Resistant, thick and tough fruit rind	Pal *et al*. 1984
	Hisar II, Acc. 3, and Ghoti	Resistant	Srinivasan 1991
	Acc. 23 and Acc. 33	Resistant	Thakur *et al*. 1992
	C 96	Stable yield, resistant	Thakur *et al*. 1992
	NBTI 1	Stable resistance	Thakur *et al*. 1994
	BG 14	Resistant, high yield	Thakur *et al*. 1996
	Kerala collection 1 and Faizabad collection 17	Resistant, high yield	Tewatia *et al*. 1997
Wild bitter gourd accessions	IC 256185 and IC 248256	High resistance	Dhillon *et al*. 2005a, b
	IC 213311, IC 248282, IC 256110, IC 248254, IC 248281, and IC 248292	Resistant	Dhillon *et al*. 2005a, b
Pumpkin	IHR 35, IHR 40, IHR 79-2, IHR 83, and IHR 86	High resistance	Nath 1966
	Arka Suryamukhi	Resistant	Mahajan *et al*. 1997
Bottle gourd	NB 29	High resistance	Nath 1966
	NB 22, NB 25, NB 28, and Pusa Smooth Purple Long	Moderate resistance	Nath 1966
Sponge gourd	NS 14	Moderate resistance	Nath 1966
Ridge gourd	NR 2, NR 5, and NR 7	Moderate resistance	Nath 1966
Round melon	Arka Tinda	Resistant	Mahajan *et al*. 1997
Wild melon	*Cucumis callosus*	High resistance	Chelliah 1970

2.12.2. Management with male-sterile technique

Sterile males are released in the fields for mating with the wild females. Sterilization is accomplished through irradiation, chemo-sterilization, or by genetic manipulation. In sterile

insect programs the terms 'sterility' or sterile insect' refer to the transmission of dominant lethal mutations that kill the progeny. The females either do not lay eggs or lay sterile eggs. Ultimately, the pest population can be eradicated by maintaining a barrier of sterile flies. A sterile insect program is species specific, and is considered an ecologically safe procedure and has been successfully used in area-wide approaches to suppress or eradicate pest insects in entire regions such as the pink bollworm, Pectinophora gossypiella in California (Walters *et al*. 2000), the tsetse fly, *Glossina austeni* in Zanzibar (Vreysen 2001), the New World screwworm, Cochliomyia hominivorax in North and Central America (Wyss 2000), and various tephritid fruit fly species in different parts of several continents (Klassen *et al*. 1994). Chemo-sterilization (by exposing the flies to 0.5g tepa in drinking water for 24 h) and gamma irradiation are the only widely tested and accepted male-sterile techniques against melon fly (Odani *et al*. 1991, Gojrati and Keiser 1974). Nakamori *et al*. (1993) found in Okinawa that frequent and intensive release of sterile flies did not increase the ratio of sterile to wild flies in some areas, suggesting that it is important to identify such areas for eradication of this pest. Eradication of this pest has already been achieved through sterile-male release in Kikaijma Islands in 1985, Amami-oshima in 1987, Tokunoshima, and the Okierabu-jima and Yoron-jima Islands in 1989 (Yoshizawa 1997, Anonymous 1991a, Anonymous 1991b, Sekiguchui 1990). In the Mediterranean fruit fly (medfly), *Ceratitis capitata*, release of sterile males increased the effectiveness of the sterile insect program (Hendrichs *et al*. 2005). The use of male-sterile and male annihilation techniques has successfully eradicated the melon fly from Japan for over 24 years (Liu 1993, Shiga 1992). However, the suppression of *B. cucurbitae* reproduction through male annihilation with cue-lure may be problematic. Matsui *et al*. (1990) reported that no wild tephritids were caught with cue-lure traps after intensification of distribution of cue-lure strings, but the mating rates of mature

females did not decrease as compared to those on control islands. Conventional sterilization based on ionizing radiation causes chromosome fragmentation without centromeres, where the chromosome fragments will not be transmitted correctly to the progeny, and can have adverse effects on viability and sperm quality, resulting in reduced competitiveness of sterilized individuals (Cayol *et al*. 1999, Mayer *et al*. 1998, Hooper and Katiyar 1971, Hilbrook and Fujimoto 1970).

Although, the sterile insect technique can be used successfully to suppress economically important pest species, conventional sterilization by ionizing radiation reduces insect fitness, which can result in reduced competition of the sterilized insects (Horn and Wimmer 2003). A transgene-based, female-specific expression method of a conditional dominant lethal gene (Horn *et al*. 2002, Atkinson *et al*. 2001; Handler 2001), has been well tested in *Drosophila melanogaster* and might be transferable to other insect pest species (Horn and Wimmer 2003, Heinrich and Scott 2000, Thomas *et al*. 2000). Thus, the transgene based, dominant embryo lethality system can generate large numbers of competitive and vigorous sterile males, and can be used successfully in a sterile insect program.

2.12.3. Management with pheromone trap

Pheromones are a class of semio-chemicals that insects and other animals release to communicate with other individuals of the same species. The key to these entire behavioral chemical is that they leave from the body of the first organism, pass through the air (or water) and reach the second organism, where they are detected by the receiver. In insects, these pheromones are detected by the antennae. Since pheromone is naturally occurring biological products, they are environmentally safe, non-target organisms are not affected, insect are less likely to develop resistance and moreover they are effective at incredibly low concentrations. Sex

pheromones have been utilized in the insect pest control program through population monitoring, survey, mass-trapping, mating disruption and killing the target pest in the trap (Bottrell 1979).

Cuelure, named after the formidable melon fly *Bactrocera cucurbitae*, is a synthetic chemical compound that mimics female melon fly sex pheromones. With cuelure, damage caused by fruit flies went down 70%, and farmers have been making a profit. In Bangladesh the adoption of sex pheromone traps by Syngenta Bangladesh Ltd. has been paralled by the govt. of Bangladesh's adoption of the concept of IPM (Integrated Pest management) whereby the more toxic pesticides are replaced by sustainable and environmentally benign mean of pest and disease control.

Research Support Program (IPM CRSP) conducted field experiments which indicate that bait trapping for fruit fly control in cucurbits with a synthetic pheromone called Cuelure and mashed sweet gourd (MSG) is highly effective. Fruit fly infestation was reduced by 53 to 73 percent and yields were raised 1.4 to 2.3 times using the traps (IPM CRSP Annual Highlights 2002-2003).

The sex attractant cue-lure traps are more effective than the food attractant tephritlure traps for monitoring the *B. cucurbitae* in bitter gourd (Pawar *et al.* 1991). Methyl eugenol and cue-lure traps have been reported to attract *B. cucurbitae* males from mid-July to mid-November (Zaman 1995; Liu and Lin 1993; Ramsamy *et al.* 1987). A leaf extract of *Ocimum sanctum*, which contain eugenol (53.4%), beta-caryophyllene (31.7%) and beta-elemene (6.2%) as the major volatiles, when placed on cotton pads (0.3 mg) attract flies from a distance of 0.8 km (Roomi *et al.* 1993). Cue-lure traps have been used for monitoring and mass trapping of the melon fruit flies in bitter gourd (Permalloo *et al.* 1998; Seewooruthun *et al.* 1998; Pawar *et al.* 1991). A number of commercially produced attractants (Flycide® with 85% cue-lure content; Eugelure® 20%; Eugelure® 8%; Cue-lure® 85%+naled; Cue-lure® 85%+diazinon; Cue-lure® 95%+naled) are available on the market, and have been found to be effective in controlling this pest

(Iwaizumi *et al.* 1991). Chowdhury *et al.* (1993) captured 2.36 to 4.57 flies/trap/day in poison bait traps containing trichlorfon in bitter gourd. The use of male lure cearlure B1® (Ethylcis-5-Iodo-trans-2-methylcyclohexane-1-carboxylate) have been found to be 4-9 times more potent than trimedlure® for attracting medfly, *Ceratitis capitata* males (Mau *et al.* 2003), and thus could be tried for male annihilation strategies of melon fruit fly area wide control programs. Jaiswal *et al.* (1997) reported that in Nepal integrated control with pheromone traps, field sanitation and bagging of individual fruits proved very effective against *Bactrocera cucurbitae*.

Males of numerous *Bactrocera* and *Dacus* species are known to be highly attracted to either methyl eugenol or cuelure (Metcalf and Metcalf 1992). In fact, at least 90 per cent species are strongly attracted to either of these attractants (Hardy 1979). Pheromone traps are important sampling means for early detection and monitoring of the fruit flies that have become an integrated component of integrated pest management.

According to Metcalf *et al.* (1983), *B. cucurbitae* was extreamly responsive to cuelure, but nonresponsive to methyl eugenol, A study carried out by Wong *et al.* (1991) on age related response of laboratory and wild adults of melon fly, *B. cucurbitae* to cuelure revealed that response of males increased with increase in age and corresponded with sexual maturity for each strain.

According to Vargas *et al.* (2000) methyl eugenol and cuelure were highly attractive kairomone lures to oriental fruit fly, *B. dorsalis* and melon fly, *B. cucurbitae*, respectively.

Yubak Dhoj (2001) reported that Fruit fly (*Bactrocera cucurbitae* Coquilet. Diptera: Tephritidae) is considered one of the production constraints in Nepal. Elsewhere integrated pest management of fruit flies (*B. cucurbitae*) is achieved by using combined control methods such as male annihilation, using cue lure and malathion in Steiners traps by disrupting mating with appropriate

field sanitation, bagging of individual fruits, using pesticides in soils and with bait spraying along with hydrolysed protein.

The most predominant fruit fly species was *B. dorsalis* (48%) followed by *B. cucurbitae* (21%), *B. correcta* (16%) and *B. zonata* (15%). Thomas *et al.* (2005) evaluated two parapheromones *viz*., cuelure and methyl eugenol for their attraction to *B. cucurbitae* in a bitter gourd field and revealed that melon flies were attracted to only cuelure traps.

Singh *et al.* (2007) tested sex attractant methyl eugenol, cuelure and food attractant protein hydrolysate for attraction to fruit flies and reported that five fliy species *viz., B. zonata, B. affinis* (Hardy), *B. dorsalis, B. correcta and B. diversa* (Coquillett) were attracted to methyl eugenol traps and two species *viz*., *B. cucurbitae* and *B. nigrotibialis* (Perkins) to cuelure traps and two species namely*, B. cucurbitae* and *B. zonata* to protein hydrolysate traps.

Vargas *et al.* (2009) evaluated various traps with methyl eugenol and cuelure for capturing fruit flies and observed that *B. dorsalis* was captured in methyl eugenol traps and *B. cucurbitae* in cuelure traps. Rakshit *et al.* (2011) assessed the economic benefits of managing fruit flies infecting sweet gourd using pheromones. In this study, a pheromone called Cuelure imported by the Bangladesh Agricultural Research Council (BARC) was used for suppressing fruit fly infesting sweet gourd. Analysis of the potential benefits of farmers adopting the Cuelure technology projects that benefits over 15 years range from 187 million Taka or $2.7 million to 428 million Taka or $6.3 million, depending on assumptions. The projected rate of return on the BARI investment in pheromone research ranges from to 140 to 165 per cent. The size of these returns implies that pheromone research at BARI has a high economic return and that Bangladesh benefits significantly as Cuelure becomes more widely available to farmers.

Vargas *et al.* (2011) reported that Phenyl propanoids are attractive to numerous species of Dacine fruit flies. Methyl eugenol (ME) (4-allyl-1, 2-dimethoxybenzene-carboxylate), cue-lure (C-L) (4-(p-acetoxyphenyl)-2-butanone), and raspberry ketone (RK) (4-(p-hydroxyphenyl)-2-butanone) are powerful male-specific lures. Most evidence suggests a role of ME and C-L/RK in pheromone synthesis and mate attraction. ME and C-L/RK are used in current fruit fly programs for detection, monitoring, and control. During the Hawaii Area-Wide Pest Management Program in the interest of worker safety and convenience, liquid C-L/ME and insecticide (i.e., naled and malathion) mixtures were replaced with solid lures and insecticides.

Hossen (2012) reported that the highest performance was achieved from Pheromone trap with funnel+Bait trap where Pheromone trap with funnel showed the second highest performance in terms of healthy, infested and total fruit yield by controlling cucurbit fruit fly and control treatment showed the lowest performance along with the treatment of T_1 (Only pheromone trap).

The genus Bactrocera consists of over 500 species distributed in the tropical and subtropical regions of Asia (Smith *et al.* 2003) and includes many serious and/or highly invasive polyphagus pest species, namely *B. correcta* (Bezzi)–guava fruit fly, *B. cucurbitae* (Coquillett)–melon fly, *B. carambolae* (Drew & Hancock)–carambola fruit fly, *B. dorsalis* (Hendel)–oriental fruit fly, *B. papayae* (Drew & Hancock)–Asian papaya fruit fly, *B. philippinensis* (Drew & Hancock)–Philippines fruit fly, *B. latifrons* (Hendel)–solanaeous fruit fly, *B. tryoni* (Froggatt)–Queensland fruit fly, *B. umbrosa* (Fabricius)–Artocarpus or jack-fruit fly and *B. zonata* (Saunders)–peach fruit fly. Males of these species, with the exception of *B. cucurbitae* and B. tryoni (both attracted to cue-lure (CL)/raspberry ketone (RK)) and *B. latifrons* (not attracted to either CL/RK or methyl eugenol (ME), are attracted to ME, a compound found in a wide diversity of plant species (Tan and Nishida 2012) and now known to be a pheromonal precursor. As discussed below, the strong

attraction of males to ME has, to some degree, limited impetus to explore sex pheromones as a trapping tool for *Bactrocera* species. Here, we summarize the chemistry of Bactrocera pheromones and note studies that have monitored male or female attraction to pheromonal emissions.

As true for most of the economically important tephritid species examined thus far, sexual signaling in *Bactrocera* typically involves the production and broadcast of sex pheromone by males (a behavior termed "calling") while resting on vegetation and detection and subsequent mate searching by receptive females. Most accounts of male calling and mating derive from laboratory or field cage observations (e.g., Kuba and Koyama 1985, Arakaki *et al.* 1984, Ohinata *et al.* 1982, Tychsen 1977), and the few field studies conducted – all on *B. dorsalis*– indicate plasticity in that species' mating system. Working in Hawaii, Shelly and Kaneshiro (1991) observed calling males and matings in the canopy of a single fruiting tree within a citrus orchard, suggestive of a lek mating system. In contrast, Stark (1995), also working in Hawaii, observed *B. dorsalis* females moving from papaya trees to non-host (Panax) trees in the late afternoon followed by males 30–60 min later.

Although their incidence was not quantified, Stark (1995) observed matings on this nonhost plant. Finally, working in Thailand, Prokopy *et al.* (1996) released *B. dorsalis* within a non-fruiting orchard and experimentally added food, water, and host fruits to the trees. In this case, and in contrast to the aforementioned studies, all sexual behavior and all matings were recorded on trees with fruits and on the fruit itself, leading the authors to suggest that the importance of host fruits as foci for sexual activity may vary with microclimatic conditions. The behavioral variability described for *B. dorsalis*, along with the lack of field studies on *Bactrocera* species in general, serves as a cautionary prelude to the following discussion: little is known about the

importance of male pheromones in sexual selection in the genus, and consequently evaluation of male pheromones as potential trap attractants is necessarily preliminary and inconclusive.

The *B. dorsalis* species complex comprises over 70 recognized species (White and Elson-Harris 1992), several of which, namely *B. dorsalis*, *B. invadens*, *B. papayae*, *B. philippinensis*, and *B. carambolae* are serious agricultural pests. Recent molecular (Krosch *et al.* 2013, Schutze *et al.* 2012, Tan *et al.* 2011, 2013), morphological (Krosch *et al.* 2013, Schutze *et al.* 2012, Mahmood 1999, 2004), behavioral (i.e., mating compatibility; Schutze *et al.* 2013, Wee and Tan 2005b, Tan 2000, 2003, McInnis *et al.* 1999), and pheromone chemistry (Tan *et al.* 2011, 2013, Tan and Nishida 1996, 1998) data have raised doubts regarding the validity of species status for these sibling taxa (except *B. carambolae*). Researcher retain the names as originally used but recognize that results obtained for one species may, if taxonomic synonymies are eventually recognized (Schutze *et al.* 2014), apply to other currently recognized species in the complex.

In the first published description on the pheromone chemistry of male *Bactrocera*, Ohinata *et al.* (1982) analyzed "smoke" produced by male *B. dorsalis* and found that trisodium phosphate was the major component (90%) with much smaller amounts of N-(2-methylbutyl) propanamide and heptacosane. Perkins *et al.* (1990a) examined an acetate extract of rectal glands of sexually mature male *B. dorsalis* from a colony maintained in Hawaii and detected the trimethyl ester of citric acid (a major component), the trimethyl ester of phosphoric acid, and dimethyl succinate along with methyl esters of fatty acids and two spiroacetals. The males sampled in this study had not fed on ME, and no biological activity was demonstrated for the compounds identified. However, Tan and Nishida (1996), Nishida *et al.* (1988a, b) demonstrated that males of *B. dorsalis* and *B. papayae* transformed consumed synthetic ME to two major pheromonal components–E-coniferyl alcohol (ECF) and 2-allyl-4,5- dimethoxy phenol (DMP), with trace

quantity of Z-3.4-dimethoxycinnamyl alcohol (detected in some males). Nishida *et al.* (1988a) also detected these compounds in wild *B. papayae* males, indicating the males had fed on ME-bearing plants in the field, and a later study (Tan *et al.* 2002) showed that *B. papayae* males that fed on an ME-bearing orchid flower contained ECF and DMP in the rectal gland. In laboratory tests, males deprived of ME did not have ECF or DMP in the rectal gland.

As an aside, *B. papayae* males visiting an orchid whose floral fragrance contained zingerone (a compound structurally similar to ME) were found to have zingerol in the rectal gland, suggesting a role in pheromone synthesis for this compound as well (Tan and Nishida 2000, 2007). More recently, Tan *et al.* (2011, 2013) found ECF and DMP in the rectal sac of ME-fed males of *B. invadens* and *B. philippinensis*. Males of *B. carambolae* differ from the aforementioned species in that they produce only ECF after ingesting ME (Wee and Tan 2005a, Tan and Nishida 1996). Moreover, the sex pheromone of *B. carambolae* contains larger amounts of endogenously produced compounds, including 6-oxo-1-nonanol (a major component that is also detected in a closely related sibling species, *Bactrocera occipitalis* (Bezzi) and a distant species, *B. umbrosa* (Perkins *et al.* 1990b)) and three minor components, N-3-methylbutyl acetamide, ethyl benzoate, and 1,6-nonanediol (Wee and Tan 2005a).

Since Nishida *et al.*'s reporting, a number of studies have demonstrated that ME consumption increases male mating success in several species in the *B. dorsalis* complex (Obra and Resilva 2013, Orankanok *et al.* 2013, Shelly 2010a, Wee *et al.* 2007, Tan and Nishida 1996, 1998, Shelly *et al.* 1996, Shelly and Dewire 1994). However, the role of pheromone composition in determining this outcome is not known with certainty. In laboratory cage assays, Kobayashi *et al.* (1978) demonstrated attraction of *B. dorsalis* females to both live males and male rectal gland extract even when males were not previously fed ME. Wee and Tan (2005a) likewise reported

zigzag anemotaxis by *B. carambolae* females to live males and endogenously produced rectal gland substances. Thus, the breakdown products of ME are not necessary to elicit female response. Nonetheless, using a wind tunnel or laboratory cages, several studies on *B. dorsalis* complex species (Wee *et al.* 2007, Hee and Tan 1998, Shelly and Dewire 1994) have reported greater female attraction to males that had previously fed on ME than to unfed males, and Khoo *et al.* (2000) and Hee and Tan (1998) showed female attraction to ECF and DMP individually (with greater attraction to ECF than DMP in these tests) and in combination. Importantly, greater female response to ME-fed males has been documented, not only using synthetic ME, but also after male feeding on natural floral (Shelly 2000a, 2001a) or fruit (Shelly and Edu 2007) sources of ME. Several studies (Wee *et al.* 2007, Wee and Tan 2005a, Hee and Tan 1998) have documented maximum female attraction to male sex pheromone at dusk, the time of peak sexual activity in *B. dorsalis* species complex. To our knowledge, only two studies have examined the long-range attractiveness of male pheromone to females in the field. In a study examining female attraction to groups (leks) of varying size, Shelly (2001b) placed *B. dorsalis* males (none of which had fed on ME) in screen-covered cups, which were in turn placed on trees situated in a circular (10 m radius) array around a central female release point.

Approximately 10% of released females were sighted near male-containing cups over all groups. In a second study also conducted on *B. dorsalis* in Hawaii, Shelly (2001c) performed two experiments in which groups of (i) ME-fed or ME-deprived males or (ii) flower-fed or flower deprived males (where the flower used [puakenikeni, *Fagraea berteriana* A. Gray ex Benth] was known to contain ME-like compounds (Nishida *et al.* 1997)) were placed in cups suspended in host trees (one male type [i.e., fed or non-fed] per tree) situated in a circle (12m radius), and females were released from the center. Compared to non-fed males, both ME and flower-fed

males were found to signal more frequently and attract greater total numbers of females as well as greater numbers of females per signaling male. These studies were not designed to test explicitly the function of pheromone signaling (since blank controls were not run in either study), but they nevertheless hint at long-range attraction mediated by male pheromone and thus suggest the potential for male pheromone as a trap bait for species in the *B. dorsalis* complex.

Data on pheromonally-mediated male-male attraction are inconsistent. In laboratory cages, *B. dorsalis* males showed no attraction to conspecific males (non-MEfed, Kobayashi *et al.* 1978). In contrast, Nishida *et al.* (1988b) found that traps baited with DMP captured as many wild males as traps baited with ME. In wind tunnel tests, Hee and Tan (1998) found that *B. papayae* males were attracted to both ME-fed and control (unfed) conspecific males but showed greater attraction to the treated males. Also using a wind tunnel, Wee *et al.* (2007) found non-ME-fed males of *B. carambolae* were attracted to ME-fed conspecific males at a much higher level than observed in the converse situation (i.e., ME-fed males responding to non-MEfed males). Moreover, field cage observations showed that unfed males aggregated around ME-fed males and fed on anal secretions of ME-fed males (Tan and Nishida 1996). Results for *B. papayae* and *B. carmabolae* thus suggest that male sex pheromone may also serve as an aggregation pheromone. However, this function implies an evolutionary advantage to aggregation per se (e.g., increased mating success), whereas the possibility remains that male-male attraction simply represents a special case of male attraction to ME (or ME-like compounds), where the ME source is a male rather than a plant. ME also acts as a pheromone precursor for both *B. correcta* and *B. zonata*. In *B. zonata*, it is transformed to two male sex pheromonal components, DMP and Zconiferyl alcohol (ZCF), although final confirmation awaits tests of biological activity on female response (Tan *et al.* 2011). In *B. correcta*, however, ME is converted to ZCF and (Z)-3,4-

dimethoxycinnamyl alcohol (ZDMC) (Tokushima *et al.* 2010). Furthermore, wild *B. correcta* males also accumulate large quantities of sesquiterpene hydrocarbons, namely β-caryophyllene, α-humulene, and alloaromadendrene, in the rectal gland in addition to, or instead of, ZCF and ZDMC (Tokushima *et al.* 2010). The distinct difference in sex pheromonal profiles, albeit having a common ZCF component, between the two sibling species, most likely, plays an important role in maintaining reproductive isolation.

Interestingly, recent comparative field tests conducted in Thailand during 2012– 2013 and based on average flies/trap/day using a similar lure dosage per trap showed that β-caryophyllene caught on average 7 (range 3–16) times more *B. correcta* wild males than ME during the first 3 days of trapping (Tan, Chinvinijkul, Wee & Nishida, unpublished data). This is the first case of a lure being more attractive than the very potent ME to a ME-sensitive Bactrocera species. Therefore, further behavioral/ecological studies, especially related to the role of the sequiterpene and its possible replacement of ME in the trapping of *B. correcta*, are warranted.

Rectal gland extracts showed the presence of (E)- and (Z)-2-methyl-1,6-dioxaspiro [4.5]decanes, 3-methylbutanol, 1,7-dioxaspiro [5.5]undecane, and 6-oxononan-ol (Perkins *et al.* 1990b). In addition, some unidentified ME metabolites (identities currently being evaluated) were detected in the rectal gland after consumption of ME by males (Nishida and Tan, unpublished data). In Malaysia, *B. umbrosa* and *B. papayae* are endemic and sympatric species as well as serious pests of jackfruit, *Artocarpus heterophyllus* Lam., but they do not interbreed. Apparent reproductive isolation was observed between the two species even when both males and females of both the species were kept together in a cage for approximately 2 months; intraspecific but no interspecific matings were observed (Tan, unpublished observations). Males of these species are attracted to RK/CL. Rectal gland secretions of *B. cucurbitae* contain N-3-methylbutyl acetamide,

two spiroacetals, and three pyrazines (Baker and Bacon 1985, Baker *et al.* 1982a). Later, ethyl 4-hydroxybenzoate (a major component) and propyl 4-hydroxybenzoate (a minor component) were also detected in the rectal gland of the melon fly (Perkins *et al.* 1990b). Nishida *et al.* (1990) showed that sexually mature male melon flies produce, endogenously in the rectal gland, relatively small quantities of N-3-methylbutyl acetamide, methoxy-acetamide, methyl, ethyl, and propyl-4-hydroxybenzoate, and a large quantity of 1,3-nonanediol, which was not detected in the previous studies. The amounts of 1,3-nonanediol and ethyl 4-hydroxybenzoate stored in the rectal gland increased with age, starting 2 weeks after adult eclosion, thus coinciding with attainment of sexual maturity (Nishida *et al.* 1990). Additionally, at sexual maturity males of *B. cucurbitae* consume and sequester RK from anthropogenic (Nishida *et al.* 1990) and natural (Tan and Nishida 2005, Nishida *et al.* 1993) sources into the rectal gland. As noted above for *B. papayae*, males of *B. cucurbitae* are also attracted to and feed on zingerone, an orchid floral volatile, and store it unmodified in the rectal gland (Tan and Nishida 2000).

Males of *B. tryoni* produce endogenously six amides as major sex pheromonal components, and three of the six, namely, N-3-methylbutyl acetamide (MBA), N-3-methylbutyl propanamide (MBP), and N-3-methylbutyl-2-methyylpropanamide, are frequently detected in the rectal gland (Bellas and Fletcher 1979). Furthermore, MBA and MBP increase significantly from 14 to 17 day-old males corresponding with attaining sexual maturity (Tan and Nishida 1995). This suggests that the two chemicals may act as close range sex pheromone. Males consume plant-borne RK or RK from spontaneous hydrolysis of CL and sequester it in the rectal gland as a major pheromonal component (Tan and Nishida 1995).

Analogous to the *B. dorsalis* complex, ingestion of CL/RK has been shown to enhance male mating success, though the effect appears short-lasting both for *B. cucurbitae* (1 day after

feeding, Shelly 2000b, Shelly and Villalobos 1995) and *B. tryoni* (1–3 days after feeding, Kumaran *et al.* 2013). More recently, *B. tryoni* males fed zingerone were also found to have a mating advantage over control males deprived this compound (Kumaran *et al.* 2013). The role of the sex pheromone in influencing male mating success is unknown. Kobayashi *et al.* (1978) found that *B. cucurbitae* females were attracted to male rectal glands as well as live males (in neither case were males fed CL/RK) but that the attraction was far weaker than that observed for *B. dorsalis* females to conspecific males. In wind tunnel trials, Khoo and Tan (2000) demonstrated that CL-fed and zingerone-fed males of *B. cucurbitae* attracted more females compared to males deprived these compounds, which strongly suggests a sex pheromonal role for these exogenous phenylbutanoids. To our knowledge, there are no laboratory or field data available investigating the effect of the male sex pheromone on female attraction or male mating success in *B. tryoni*.

Bactrocera oleae (Rossi) [formerly *Dacus oleae* (Gmelin)], the olive fruit fly, unlike the other major pest *Bactrocera* species mentioned above, is a monophagous pest species. Additionally, the species differs from other *Bactrocera* in that the *B. oleae* females attract males for mating and not vice versa (Haniotakis 1974). Baker *et al.* (1980) identified the major component of the female sex pheromone as (1,7-dioxaspiro[5.5]undecane. Additional studies (Mazomenos and Haniotakis 1981) confirmed this finding and also identified three minor components, o-pinene, n-nonanal, and ethyl dodecanoate, in the female pheromone (Baker *et al.* 1982b). Other components of the female sex pheromone were reported (Gariboldi *et al.* 1982), but their isolation and biological activity (tested with synthetic products) was not corroborated (Mazomenos 1989, Jones *et al.* 1983). Interestingly, olean was also isolated from the rectal gland of male *B. oleae* along with other components (Mazomenos and Pomonis 1983).

Canale *et al.* (2012) reported that, among males, olean production is greatest among young males (5–8 days old) and then ceases by 11 day of age. Also, in a recent finding, Carpita *et al.* (2012) identified (Z)-9-tricosene from male rectal gland extracts and reported female attraction to this compound in synthetic form. Several studies (Mazomenos and Haniotakis 1981, 1985,Haniotakis 1974) have demonstrated male attraction to natural or synthetic components or whole blends of the female pheromone in *B. oleae*. Laboratory and field experiments demonstrated that olean was more attractive than the remaining three components but that the combination of all four components was more attractive than olean alone. More detailed chemical analysis (Haniotakis *et al.* 1986a) revealed that olean exists as (R) and (S) mirror (stereo) image enantiomers, (R)-olean and (S)-olean and that (i) males are more strongly attracted to (R)-(-)-oleanthan(S)-(+)-olean, (ii) the converse was true for females, and (iii) overall, males showed greater attraction to response to the compound than did females. Haniotakis *et al.* (1986a) suggest olean may serve an aggregation or aphrodisiac function for females. Relative to the strong evidence gathered for male attraction to the female sex pheromone, data regarding female attraction to male olfactory signals are less conclusive. Mazomenos and Pomonis (1983) reported negligible female response in laboratory tests to extracts of rectal glands of mature males. More recently, however, Mavraganis *et al.* (2010) demonstrated that whole body extracts of *B. oleae* males were highly attractive to females and suggest that the previous negative results may have reflected low pheromone concentrations in the rectal gland extracts compared to those of whole body. Benelli *et al.* (2013) found that young males, which, as noted above, produce olean at higher levels than old males, did not have a mating advantage over older individuals.

In contrast to the other economically important species discussed here, several studies have demonstrated the usefulness of olean in baiting traps. In general, because olean is primarily a

male attractant, the most effective traps appear to be those that combine the pheromone with ammonium or some other food bait that targets females (Broumas and Haniotakis 1994, Haniotakis and Vassiliou-Waite 1987). Traps baited with this combination have been used both in detection (Yokoyama *et al.* 2006, Rice *et al.* 2003) and in mass-trapping efforts to lower olive infestation (Noce *et al.* 2009, Petacchi *et al.* 2003, Iannotta *et al.* 1994, Haniotakis *et al.* 1986b, 1991).

2.12.4. Management with poison bait trap

Niranjana and Raveendranath (2002) carried out a study in Maha (October 2000-January 2001) to evaluate the efficacy of trapinol trap and sugar baited trap on fruit flies of cucurbits. It was followed by another study in Yala (April 2001- July 2001) was carried out to find out the efficacy of petroleum spirit extract of cloves as trapping agent of cucurbit fruit flies and found that, the number of fruit flies caught in trapinol trap and trap with extract of clove was significantly higher than the control and sugar baited trap. There was no significant ($P>0.05$) difference between control and sugar baited trap. However, the number of fruit flies caught in the trapinol was significantly higher than the clove extraction.

Uddin (2002) reported that the number of flies were higher at early fruiting stage and the ratio of male and female flies in bait traps at different reproductive stages of plants does not showed significantly difference.

Samalo *et al.* (1995) reported that baiting with dichlorvos, monocrotophos or quinalphos at a concentration of 0.025% killed 100% of adults within 6 h, as compared with 6.6% mortality in a 10% sugar solution. Contact toxicity tests showed that chlorpyrifos, endosulfan and dichlorvos caused 100% mortality of adults in 18 h as compared with 3.3% mortality of untreated adults.

Chowdhury *et al.* (1993) captured 115.16 to 167.48 flies/ trap/ season in poison bait traps containing trichlorfon in bitter gourd.

Bangladesh Agricultural Research Institute has developed a simple and cheap method of poison bait trap which showed 31.18-95.07% reduction of fruit infestation in cucurbit fruit as compared to those in untreated plots (Nasiruddin 1991).

In a study (Anon. 1990) the rate of fruit infestation was 15.34% and 15.36% respectively in baited and bait sprayed, and was significantly lower than 36.55% in control plot of bitter gourd. Nasiruddin and Karim (1992) reported a lower rate of infestation in snake gourd (6.47%) when treated with bait spray (Dipterex+molasses) compared to control (22.48%). Steiner *et al.* (1988) reported that poison bait containing malathion and protein hydrolysate gave good result in controlling fruit flies on squash and melon.

In Hawaii, squash and melon fields were often surrounded by a few rows of corn as trap crop. Corn plant which were treated with poison bait containing malathion and protein hydrolysate attracted a large number of fruit flies to the trap plants leaving a very few for infesting squash or melon (Van den Boech and Messenger, 1973). Lall and Singh (1969), in tests of bait traps, the catches of flies were highest with mixtures of either citronella oil, dried mango juice, palm juice and diazinon or sugar, palm juice and diazinon. The increase in yield of melon using poison bait technique has also been reported by Stonehouse *et al.* (2002).

2.12.5. Management with spinosad

Spinosad is a natural compound with insecticidal activity that has many properties considered to be highly desirable for insect control programs (Sparks *et al.* 2001). This compound has been shown to be highly effective on a wide range of pest species, yet at the same time appear to have

limited impact on non-target organisms, including mammals, that may be exposed to it. Moreover, spinosad is readily degradable by exposure to sunlight, thus minimizing any environmental burden that may occur as a result of widespread use. Spinosad acts as a stomach poison, although spinosad it is activated by both contact and ingestion (BCPC 2006). Spinosad was originally collected from a Caribbean island in 1985 (Sparks *et al.* 2001), and the formulation that is currently the most widely used as an insecticide consists primarily of the A and D forms of this compound, both of which are naturally produced by the bacterial species *Saccharopolyspora spinosa*. Insecticide compounds based on spinosad have been extensively used as agents for control of insect pest species in the Diptera, Lepidoptera, Coleoptera, and Hymenoptera orders (Hertlein *et al.* 2010) among others. Within the Diptera, spinosad has been shown to be effective for control of Tephritid species within the *Ceratitis, Bactrocera, Rhagoletis*, and *Dacus* genera (Sparks*et. al.* 2001). As with any compound used for control programs, however, one concern over such widespread use is the potential for resistance to this compound to arise either in laboratory and/or natural populations. Indeed, the history of both natural and artificial compounds used for insect control is replete with examples of resistance development even where much more highly toxic compounds such as DDT or malathion have been used (Magana *et al.* 2007, Georghiou 1986). For most of the past forty years, organophosphate-(OP) compounds were the sole insecticides used to suppress this pest. Recently, due to growing environmental concerns raised over the use of OPs, alternatives such as spinosad have also been used (Vargas 2008, Barry *et al.* 2006). As part of a formulation known as GF-120 (Dow AgroSciences, Indianapolis, IN, USA), spinosad has been employed as part of an area-wide fruit fly pest management program (HAW-FLYPM) to control melon flies in Hawaii since 2002 (Mau 2007, Mau 2006), and in central Taiwan since 2007.

These values were also higher than those obtained from similar studies looking for possible delays in response to spinosad for other species such as *B. dorsalis* (Hsu and Feng 2006). In terms of field applications, spinosad has been used since 2004 for control of *B. oleae* in California (Kakani 2010) and in Hawaii for control of both *B. cucurbitae* and *B. dorsalis* since 2000.

2.12.6. Management with bait spray

The cucurbit fruit flies have long been recognized to be susceptible to attractants. Presently the poison baits used for cucurbit fruit flies are 20g Malathion 50 percent or 50ml of Diazinon plus 200g of molasses in 2 liter of water kept in hot containers or applying the bait spray containing Malathion 0.05 percent plus 1 percent sugar/molasses or 0.025 percent of protein hydrolysate (20ml of malathion 50EC and 200g of sugar/ molasses in 20 liter of water) or spraying plants with 500g molasses plus 50g malathion in 50 liter of water or 0.025 percent Fenitrothion plus 0.5 percent molasses. This is repeated at weekly intervals were the fruit fly infestation is serious (Kapoor 1993). Chaudhary and Patel (2008) reported higher yield of pumpkin with combined use of male annihilation technique and poison bait spray.

Agarwal *et al.* (1987) achieved very good results for fruit fly (*D. cucurbitae*) management by spraying the plants with 500g molasses and 50g malathion in 50 liter water at 7 days intervals. In Hawaii, poison bait containing malathion and protein hydrolysate gave better results in fruit fly management program (Steiner *et al.* 1988).

Kiran Rana and Kanwar (2014) reported that combined treatment of cue-lure baited traps and poison bait spray was most effective in management of fruit flies with significantly less fruit damage as compared to control rather than their separate applications. Chaudhary and Patel (2008) reported higher yield in pumpkin with combined use of male annihilation technique and

poison bait spray. Raghuvanshi *et al.* (2008) and Chaudhary and Patel (2008), Vargas *et al.* (2005) also reported similar results that poison bait spray and male annihilation techniques in combination proved to be efficient in suppression of fruit flies in Hawaii. However, deployment of indigenous bait traps along with cuelure traps may further reduce melon fly damage and increase yield as observed by Nasiruddin *et al.* (2002). Kiran Rana and Kanwar (2014) reported that evaluation of eco-friendly techniques for management of melon fruit flies (*Bactrocera* spp.) in bitter gourd (*Momordicacharantia* L.).

Baiting (with malathion in protein bait sprays) is a good method for the control of *B.aquilonis* and *B. jarvisi* on fruits and vegetables in home gardens in the north territory of Australia (Smith 1992). It is advisable to spray the lower surface of leaves as these flies have the habit of resting there. The flies are attracted to sugar solution and are killed while trying to feed on them. The time of repeated applications is adjusted in such a way that it is less than the required time for the sexual maturation of newly emerged adult flies. This is useful for efficient destruction of the population as a whole, rather than only the individuals (Kapoor 1993).

Nasiruddin and Karim (1992) reported that bait spray (1.0g Dipterex 80SP and 100g of molasses per liter of water) on snake gourd against fruit fly (*Bactrocera cucurbitae*) showed 8.50% infestation compared to 22.48% in control. A field study was conducted to evaluate the efficacy of some bait sprays against fruit fly (*Bactrocera cucurbitae*) in comparison with a standard insecticide and bait traps. The treatment comprised 25g molasses+2.5 ml Malathion, (Limithion SOEC) and 2.5 litres water at a ratio of 1:0.1:100 satisfactorily reduced infestation and minimized the reduction in edible yield (Akhtaruzzaman *et al.* 2000).

2.12.7. Management with neem oil

Botanical insecticides are plant derivatives which have insecticidal properties against pest. Neem oil is used as botanical in the experiment. Neem oil is a naturally occurring pesticide found in seeds from the neem tree (*Azadirachta indica*). It is the most important of the commercially available products of neem for organic farming and medicines. It has been used for hundreds of years to control pests and diseases. Neem oil is a mixture of components. It is composed mainly of triglycerides and contains many triterpenoid compounds, which are responsible for the bitter taste. It is hydrophobic in nature and in order to emulsify it in water for application purposes, it must be formulated with appropriate surfactants. Neembecidine is such an insecticide derived from seed kernel mixed with other preservatives. Besides this fresh neem seed kernel could be used for this purpose. Neem derivatives have been demonstrated as repellents, antifeedants, growth inhibitors and chemosterilant (Butterworth and Morgan 1968; Leuschner 1972; Steets 1976). Singh and Srivastava (1985) found that alcohol extract of neem oil, *Azadirachta indica* (5%) reduced oviposition of *B. cucurbitae* on bittergourd completely and its 20% concentration was highly effective to inhibit oviposition of *B. zonata* on guava.

Azadirachtin is the most active component for repelling and killing pests and can be extracted from neem oil. It reduces insect feeding and acts as a repellent. It also interferes with insect hormone systems, making it harder for insects to grow and lay eggs. Azadirachtin can also repel and reduce the feeding of nematodes. Stark *et al.* (1990) studied the effect of Azadirachtinon metamorphosis, longevity and reproduction of *Ceratitis capitata, B. cucurbitae* and *B. dorsalis*. Khalid (2009) found that in laboratory test, both neem oil and neem seed water extract at 10,000ppm adversely affected the settling of cucurbitfruit fly.

2.12.8. Management with biological control agent

There are no reports on the successful use of bio-control agents against the melon fruit fly. Srinivasan (1994) reported *Opius fletcheri* Silv. to be a dominant parasitoid of *B. cucurbitae*, but the efficacy of this parasitoid has not been tested under field conditions in India. The parasitization of *B. cucurbitae* by *O. flatcheri* has been reported to vary from 0.2 to 1.9% in *M. charantia* fields in Honolulu at Hawaii (Wong *et al*. 1989). Similar level of parasitization (<3%) was also reported from northern India by Nishida (1963). However, Nishida (1955), Newell *et al*.(1952) and Willard (1920) have reported parasitization at levels of 80, 44, and 37%, respectively, from Hawaii. Thus, there is a need to reevaluate the parasitization potential of *O. flatcheri* before its exploitation as biocontrol agent for the management of *B. cucurbitae*. More recently, a new parasitoid, *Fopius arisanus* has also been included in the IPM program of *B. cucurbitae* at Hawaii (Wood 2001). A Mexican strain of the nematode, *Steinernema carpocapsae* Weiser (*Neoaplectana carpocapsae*), has been reported to cause 0 to 86% mortality to melon fruit fly after an exposure of 6 days to 5000 to 5,000,000 nematodes/cup in the laboratory, and an average of 87.1% mortality under field conditions when applied at 500 infective juveniles/cm^2 soil (Lindegren 1990). Sinha (1997) reported that culture filterate of the fungus, *Rhizoctonia solani* Kuhn, to be an effective bio-agent against *B. cucurbitae* larvae. While, the fungus, *Gliocladium virens* Origen, has been reported to be an effective against *B. cucurbitae* (Sinha and Singh 1998). Culture filtrates of the fungi *R. solani*, *Trichoderma viridae* Pers., and *G. virens* affected the oviposition and development of *B. cucurbitae* adversely (Sinha and Saxena 1999).

The efficacy of most of these bio-agents is unclear under field conditions. Therefore, there is a need to evaluate the efficacy of these bio-control agents against *B. cucurbitae* for practical use in integrated pest management programs.

2.12.9. Management with chemical control

Chemical control of the melon fruit fly is relatively ineffective. However, insecticides such as malathion, dichlorvos, phosphamidon, and endosulfan are moderately effective against the melon fly (Agarwal *et al.* 1987). Bhatnagar and Yadava (1992) reported malathion (0.5%) to be more effective than carbaryl (0.2%) and quinalphos (0.2%) on bottle gourd, sponge gourd and ridge gourd. The application of molasses+malathion (Limithion 50EC) and water in the ratio of 1:0.1:100 provides good control of melon fly (Akhtaruzzaman *et al*. 2000). Application of either 0.05% fenthion or 0.1% carbaryl at 50% appearance of male flowers, and again at 3 days after fertilization is helpful in reducing the melon fly damage (Srinivasan 1991). Gupta and Verma (1982) reported that fenitrothion (0.025%) in combination with protein hydrolysate (0.25%) reduced fruit fly damage to 8.7% as compared to 43.3% damage in untreated control. Application of carbofuran granules at 1.5 kg a.i./ ha at the time of sowing, vining, and flowering gave 83.35% protection to bitter gourd against *B. cucurbitae* (Thomas and Jacob 1990). Dicrotophos (at 600g a.i./ha) and trichlorfon (at 1920g a.i./ha) has been found to give good control of *B. cucurbitae* in muskmelon (Chughtai and Baloch 1988). Formathion is more effective than trichlorfon (Talpur *et al*. 1994). Diflubenzuron has also been reported to be effective in controlling the melon fly (Mishra and Singh 1999). Reddy (1997) reported triazophos to be the most effective insecticide against this pest on bitter gourd. Highest yield and lowest damage were observed in pumpkin when treated with carbofuran at 1.5 kg a.i./ha at 15 days after germination (Borah 1998). An extract of Acorus calamus (0.15%) reduced the adult longevity from 119.2 days to 26.6 days when fed continuously with sugar mixed with extract (at 1ml/g sugar) (Nair and Thomas 1999). Neem oil (1.2%) and neem cake (4.0%) have also been reported to be as effective as dichlorvos (0.2%) (Ranganath *et al*. 1997).

2.12.10. Mamagement with cultural practices

Local area management

Local area management means the minimum scale of pest management over a restricted area such as at field level/crop level/village level, which has no natural protection against reinvasion. The aim of local area management is to suppress the pest, rather than eradicate it. Under this management option a number of methods such as bagging of fruits, field sanitation, protein baits and cue-lure traps, host plant resistance, biological control, and soft insecticides, can be employed to keep the pest population below economic threshold in a particular crop over a period of time to avoid the crop losses without health and environmental hazards, which is the immediate concern of the farmers (Dhillon *et al*. 2005a).

Bagging of Fruit

Bagging of fruits on the tree (3 to 4 cm long) with 2 layers of paper bags at 2 to 3 day intervals minimizes fruit fly infestation and increases the net returns by 40 to 58% (Fang 1989a, b; Jaiswal *et al*. 1997). Akhtaruzzaman *et al*. (1999) suggested cucumber fruits should be bagged at 3 days after anthesis, and the bags should be retained for 5 days for effective control. It is an environmentally safe method for the management of this pest.

Field sanitation

The most effective method in melon fruit fly management uses primary component- field sanitation. To break the reproduction cycle and population increase, growers need to remove all unharvested fruits or vegetables from a field by completely burying them deep into the soil. Burying damaged fruits 0.46 m deep in the soil prevents adult fly eclosion and reduces population increase (Klungness *et al*. 2005).

2.12.11. IPM packages against cucurbit fruit fly

Fruit fly IPM systems range from programs for individual homeowners and farmers to large areas of many square kilometers. During the twenty first century the Regional Fruit Fly Project in the Pacific pioneered the implementation of sustainable technologies throughout many Pacific Island Countries for control of *Bactrocera* fruit flies (Allwood *et al.* 2015, Allwood *et al.* 2001). These technologies included fipronil-based bait sprays and male annihilation treatments, in conjunction with cultural controls. Similarly, the HAWPM program tested and demonstrated larger IPM programs to control *B. dorsalis* and *B. cucurbitae* that included: (1) field sanitation, (2) protein bait, (3) lures, (4) SIT and (5) biological control (Vargas *et al.* 2008). This program registered many technologies for farmers and homeowners and promoted the use of safer or reduced risk fruit fly protein baits and MAT traps in what became popularly referred to as the "1 (sanitation), 2 (protein bait), 3 (male lure trapping) approach" for fruit fly control (Mau *et al.* 2009). For example, in a study that aimed at assessing the efficacy of GF-120 NF Naturalyte Fruit Fly Bait sprays in conjunction with field sanitation to control *B. dorsalis* in papaya orchards in Hawaii, Piñero *et al.* (2009) reported significant reductions in numbers of female *B. dorsalis* captured by monitoring traps and in levels of infestation of papaya fruit by *B. dorsalis* only when both GF-120 was applied in a sustained manner in conjunction with field sanitation and male annihilation.

Asian and African countries have also demonstrated the ability to control major pest species, with some examples from India presented here. As discussed above, Verghese *et al.* (2004) evaluated the effectiveness of an IPM package targeting *B. dorsalis* in mango orchards in India with good results, integrating MAT, field sanitation and insecticide sprays. Best results were obtained when MAT, sanitation and delta-methrin were combined with azadirachtin over a two-year period. In a study conducted in mango orchards in India, Singh *et al.* (2013) reported that *B.*

*dorsalis*and *B. zonata* (Saunders) were effectively suppressed by integrating multiple approaches. Maximum fruit protection (94.5%) was recorded with integration of MAT+sanitation+soil drenching with 0.1% chorpyriphos+bait cover spray (0.05% malathion+0.2% Protinex). This was followed by a combination of MAT+sanitation+soil drenching (87.3% protection), MAT+sanitation+cover spray (81.8% protection) and MAT+sanitation (65.5% protection). Clearly, the removal of soil drenching or bait cover sprays reduced the effectiveness of the crop protection program, highlighting the need to include chemical controls into suppression programs of aggressive species, such as *B. dorsalis*. Gogi *et al.* (2014) reported a reduction in infestation of *Momordica charantia* L. by *B. cucurbitae*, leading to increased marketable yields through the integration of three components of cultural management: (1) Early sowing, (2) Hand Sowing Method (HSM), and (3) sanitation.

Although *B. oleae* is more of a sub-tropical than a tropical pest species, methods to manage it have been similar to tropical species. Integrated control of *B. oleae* was proposed soon after the pest was found in the olive production areas of California (Collier and Van Steenwyk 2003). Recommendations for commercial orchards included releases of biological control parasitoids (*Psyttalia humilis* (Silvestri), *P. concolor* (Szépligeti), and *P. lounsburyi* (Silvestri)), cultural controls, attract-and-kill traps and GF-120 NF Naturalyte Fruit Fly Bait. Sanitation has been a major consideration, accomplished by removing all unharvested fruits and standing water in orchards that provide adults with water (Yokoyama 2015). Attract-and-kill traps (Johnson *et al.* 2006) used as bait stations have shown promise for *B. oleae* control and greatly reduce the amount of bait spray applied in olive orchards because they attract the pest to an attractive device that contains the toxicant (Yokoyama 2014, Yokoyama 2014).

Most challenging have been the accidental introductions of fruit flies into the US mainland. Recently STATICTM Spinosad-ME, developed late in the HAWPM program, has been registered in California and Florida for use with GF-120 against accidental introductions of *Bactrocera*. In addition, lambda-cyhalothrin has been tentatively approved as a replacement for diazinon for use as a soil drench in Florida. Research continues on the possible use of Entrust SG as a biopesticidal soil drench as part of a three-pronged area-wide IPM system for control of fruit flies accidentally introduced into the U.S. mainland (Stark *et al.* 2014). One of the largest multi component programs used on the U.S. mainland covers over 5000 km^2 in California and Florida. The primary technology used is the release of millions of sterile *C. capitata* flies. When infestations are found, the program is supplemented with fruit stripping and treatment of host trees with GF-120. This same SIT approach could also be used for suppression of many *Bactrocera* fruit flies (e.g., *B. dorsalis* and *B. cucurbitae*) if it was not for the effectiveness of MAT (Vargas *et al.* 2015).

Scientists of BARI, collaborating with the USAID funded IPM CRSP programs, have developed a simple, relatively inexpensive IPM based method to combat the cucurbit fruit fly problem. The method consists of (a) clean cultivation, and (b) use of traps baited with synthetic sex pheromone 'cuelure' in combination with poison traps baited with mashed sweet gourd (MSG trap) (Nasiruddin *et al.* 2004).

The combined use of pheromone and MSG bait catches more flies and keep lower the fruit infestation and higher economic returns in cucumber (Nasiruddin *et al.* 2004).

The combined use of pheromone traps baited with 'cuelure' along with MSG bait trap captured 2.3 times higher number of fruit flies than that caught in MSG bait traps alone. Three times less

infestation and 2.8 times more yield were recorded at Kashimpur during winter 2001 from the sweet fields having joint treatment of pheromone and MSG traps (Nasiruddin *et al.* 2004).

Baiting with culelure+MSG has the greatest advantage in fruit fly control in bitter gourd field (Rajotte 2003).

The recent wide area management program eradication program of *B. cucurbitae* in Seychelles demonstrated a three tier model including a) initial population reduction using bait sprays, b) elimination of reproduction using parapheromone lure blocks to eradicate males and thus prevent oviposition by females, and c) intensive surveying by traps and fruit inspection, until it can be certain that the pest is entirely eradicated (Mumford 2004).

An IPM program that used field sanitation, protein bait applications, male annihilation, and release of sterile flies and parasites reduced fruit fly infestation from 30 to 40% to less than 5%, and cut organophosphate pesticide use by 75 to 90% (Vargas 2004).

The USDA-ARS areawide IPM programs of melon fruit fly started in 1999 in collaboration with the Hawaiian State Department of Agriculture and University of Hawaii, using the environmentally sound strategies such as field sanitation, male annihilation with male lures and attractants, protein bait sprays/traps, augmentative releases of biological control agents (*Fopius arisanus* and *Psyttalia fletcheri*), and sterile insect release. It has proved to be economically viable, environmentally sensitive, sustainable, and has suppressed fruit flies below economic thresholds with the minimum use of organophosphate and carbamate insecticides (Klungness *et al.* 2005, Vargas *et al.* 2003, Mau*et al.* 2003b, Wood 2001).

Pheromone trap in combination with poison bait trap (T_5) contributed to produce the highest number of fruit at early (26.67 fruit/plot), mid (37.33 fruit/plot) and late (27.00 fruit/plot) fruiting stage; total weight of fruit (838100 gm/plot) and reduced the maximum fruit infestation over

control at early (94.23%), mid (94.48%) and late (85.05%) fruiting stage. The highest yield (24.03 t/ha) was recorded in T_5 which contributed to increase the highest yield (163%) over control. The yield of bitter gourd was negatively correlated with the fruit infestation by number at early, mid and late fruiting stage (r=0.795, r=0.910 and r=0.937, respectively). The fruit yield was strongly and positively correlated with the length (r=0.972), girth (r=0.938), single fruit weight (r=0.931) and number of fruit per plant (r=0.932), i.e., yield of bitter gourd increased with the increase of the length, girth, single fruit weight and number of fruit per plant (Mahpara 2015).

A combination of methods such as (i) plowing well the soil to expose the pupae to birds, (ii) removing and destroying the infested fruits and fallen fruits regularly, (iii) covering of fruits immediately after fruit-set with polythene bag having pin-holes and (iv) spraying cypermethrin at 10 days interval or spraying bait spray made of 1.0g Dipterex 80SP and 100g molasses per litre of water or (v) placing above the crop canopy with the support of bamboo sticks the pheromone bait traps each consisting of a 2.5x1.5cm cotton wad having soaked 15-20 drops of a pheromone bait “Cuelure” {4-(p-acetoxyphenyl)-2 butane} or {4-(3-oxobutyl-phenylacetate)} and hung by a thin wire through the center of a 3-litre capacity and 22cm tall rectangular or round plastic container having two opposite cut holes and containing soapy water of 3-4cm height with a gap of 3-4cm from the hung cotton wad above (vi) using poison bait traps @ 20 to 40 per hectare, each trap made of 100g mashed ripe sweet gourd (MSG) with 0.25g Mipcin 75WP or Sevin 85WP or Dipterex 80SP in 100ml water placed in a lower smaller earthen pot at 50cm height above ground with another slightly bigger flat earthen plate placed upside-down at 20cm above it as cover, and both placed in a three split bamboo stick erected up anchored in soil. The bait

materials i.e. MSG and insecticides should be changed at every 4 days interval (Rahman 2005, Islam 1999, Roy 1997, Satter and Uddin 1996).

Cuelure+methyl eugenol+naled captured significantly more fruit flies (269) than any other treatment. It was followed by cuelure liquid+5% dibrom (185) and 92% cuelure+8% naled (172). The results suggested that pheromone and indigenous bait traps have great potential for use as control techniques for fruit fly IPM.

The mean values of infestation at all stages of reproduction under IPM package 3 (Cypermethrin applied at15 days intervals+bagging fruits at 3 DAA and left for 5 days+bait trap) was lower (3.54%) but statistically similar to that of package 2(Cypermethrin at 15 days intervals+bait spray with Malathion+molasses+bait trap) and package 4 (hand picking of infested fruits+bait trap). The rates of infestation of fruits harvested from plots subjected to package 1 (hand picking of infested fruit+bagging of fruits at 3 DAA and left for 5 days) and package 5 (hand picking of infested fruits+bait trap) were significantly higher (Akhtaruzzaman 1999).

Kairomonal attractant cue-lure [4-(p-acetoxyphenyl)-2-butanone] traps are highly effective for monitoring and mass-trapping of *B. cucurbitae* in bitter gourd and other crops (Vargas *et al.* 2000, Pawar *et al.* 1991). Similarly, protein baits are highly attractive to female melon flies (Kumar *et al.* 2011). Sex pheromone lures are effective against *D. indica* moths (Wakamura *et al.* 1998) and they are now commercially available.

Since application of chemical pesticides against melon fly may not be effective, attractants can be combined with small quantities of pesticides to develop an 'attract and kill' system. For example, protein bait sprays mixed with chemical pesticides can be spot-sprayed on the roosting host plants of melon fly. Crops like maize, cassava, sorghum and castor should be planted around the main crop (bitter gourd, water melon, etc). These roosting host plants can be spotsprayed

with protein bait sprays once a week (or more often during the wet season) to kill the newly emerged flies before they mature (Mcquate 2011, Vargas *et al.* 2008). Since both melon fly and *D. indica* can develop insecticide resistance rapidly (Chen 2002), chemical pesticides should be selected and applying with care.

Hoeing under the tree canopy at 15 days interval along with collection of fallen fruits and burying deep in the soil and spray of spinosad was found to be most effective reducing the average fruit fly infestation to 6% and 6.3% for the year 2013 and 2014 respectively with cost benefit ratio of 1: 14.7 (Khan *et al.* 2017, Haider 2011).

An IPM program that used field sanitation, protein bait applications, male annihilation, and release of sterile flies and parasites reduced fruit fly infestation from 30 to 40% to less than 5%, and cut organophosphate pesticide use by 75 to 90% (Vargas 2004).

CHAPTER III

MATERIALS AND METHODS

A set of four experiments was conducted to achieve the objectives as designed for this researchthat are given below:

Experiment 1: Study on the host preference of fruit fly and damage assessment of cucurbit fruit fly in commonly cultivated cucurbitaceous vegetables

Experiment 2: Study on the bio-ecology of cucurbit fruit fly while infesting cucurbitaceous vegetables

Experiment 3: Evaluation of the efficacy of management practices along with bio-pesticides against cucurbit fruit fly

Experiment 4: Development of Integrated Pest Management (IPM) approach for combating cucurbit fruit fly

DETAILS OF THE METHODOLOGIES

3.1. Experiment 1:Study on the host preference of fruit fly and damage assessment of cucurbit fruit fly in commonly cultivated cucurbitaceous vegetables

3.1.1. Objectives

1. To identify the resistant or least preferred cucurbits against fruit fly.
2. To assess the level of infestation of fruits caused by cucurbit fruit fly.

The experiment on the host preference and damage assessment of cucurbit fruit fly in cultivated cucurbitaceous vegetable were carried out at the experiment field of the Sher-e-Bangla

Agricultural University (SAU), Dhaka, Bangladesh during March, 2016 to July, 2016. The materials and methods adopted in this study are discussed in the following sub headings:

3.1.2. Location

The experimental site was located at the horticultural experimental farm of SAU, Dhaka-1207. The experimental field was located at 90°33'5'' east longitude and 23° 77'4'' North latitude at a height of 4 meter above the sea level. The land was medium high and well drained.

3.1.3. Climate

The experimental site was situated in the sub-tropical climatic zone, characterized by lower rainfall during the month of March, 2016 to July, 2016. Monthly maximum and minimum temperature, relative humidity and total rainfall recorded during the period of study at the SAU experimental farm have been presented in the Appendix III. The monthly average temperature, relative humidity and rainfall for the crop growing period of experiment were collected from the Bangladesh Meteorological Department (Climate Division), Agargaon, Dhaka-1207 and has been presented.

3.1.4. Soil

The soil of the study was silty clay in texture. The area represents the agroecological zone of "Madhupur Tract" (AEZ No. 28). Organic matter content was very low (0.82%) and soil pH varied from 5.47 to 5.63.

3.1.5. Design and layout

The study was conducted considering two factors- varieties (local and hybrid) and types of cucurbits (nine treatments) for evaluating host preference and damage assessment of common leaf cultivated cucurbitaceous vegetable against fruit fly. The experiment was laid out in a Randomized Complete Block Design (RCBD) two factors with three replications in the field of

the horticultural experimental field. The whole field was divided into three blocks of equal size and each block was sub divided into sixteen plots. The unit plot size was 2m × 1.5m accommodating eight pits per plot. The distance between row to row was 0.75 m and that of the pit to pit was 0.50 m.

3.1.6. Land preparation

The soil of the experimental field was well prepared thoroughly followed by plowing and cross plowing, leveling and laddering to have a good tilth. All weeds and debris of previous crops were removed and land was finally prepared with the addition of basal dose of well decomposed cow dung. The plots were raised by 10cm from the soil surface keeping the drain around the plots.

3.1.7. Manuring and fertilization

The following doses of manure and fertilizers were applied as per recommendation of Rashid (2006) for cucurbits.

Manure/ Fertilizers	**Dose per hectare**
Cow-dung	10 tons
Urea	360 Kg
Triple Super Phosphate (TSP)	150 Kg
Muriate of Potash	250 Kg

The full dose cow-dung and TSP were applied as basal dose during final land preparation. One-third of the MP and urea were applied in the pits one week before transplanting and rest of the MP and urea were applied as the top dressing at 21, 35 and 50 days after transplanting.

3.1.8. Materials used

For this study, the seeds of eight cucurbitaceous vegetables both local and hybrid of each varieties were collected from Siddik bazar, Gulistan, Dhaka. The cucurbits cultivated for this study were local and hybrid varieties of cucumber, ridge gourd, snake gourd, sweet gourd/pumpkin, sponge gourd, bitter gourd, bottle gourd and ash gourd.

Local varieties of cucurbits

Hybrid varieties of cucurbits

Plate 2. Cucurbit seed used for study

3.1.9. Raising of seedling and transplanting

Eighteen small seed beds measuring 1m × 1m were prepared and seeds were sown in the nursery bed at SAU Experimental farm on 10 March 2016. Standard seedling raising practice was followed (Rashid, 2006). The seed bed as well as the experimental plots were lightly irrigated and mulched for ensuring proper seed germination, proper growth and development of the seedlings. After twenty days of seed sowing, healthy seedlings were transplanted on 24 March 2016 in the horticultural experimental field.

Plate 3. Main field of the study

3.1.10. Intercultural operations

3.1.10.1. Thinning

Four seedlings were transplanted in each pit. After one week two healthy seedlings were kept for the study and remains were thinned out.

3.1.10.2. Irrigation

After thinning light irrigation was given to each pit. Supplementary irrigation was applied at an interval of 2-3 days. Stagnant water was effectively drained out at the time of over irrigation. Urea was top dressed in three splits as mentioned earlier.

Plate 4. Watering in the filed

3.1.10.3. Weeding

Weeding was done as and when necessary to break the soil crust and to keep the plots free from weeds. First weeding was done after 20 days of planting and the rest were carried out at an interval of 15 days to keep the plot free from weeds.

3.1.10.4. Earthing up

Earthing up was done in each pit to provide more soil at the base of each plant. This was done 40 and 60 days after transplanting.

Plate 5. Some intercultural operations were done in the experimental field

3.1.11. Treatments for the study

The experiment was evaluated to determine the host preference and damage assessment of fruit fly cultivated cucurbitaceous vegetables. The cucurbit crops were used as treatments as well as their hybrid and local name are given below:

Table 3.1.1. List of local and hybrid cucurbit varieties as treatment

Cucurbit crop	Local variety	Hybrid variety
Bitter gourd	Taj 88	Papiya
Ridge gourd	Rupali Loskor	Long green
Sponge gourd	White sweet	Jamuna
Snake gourd	Anika 7	Asha
Sweet gourd	Monika	Sweet Babu
Cucumber	Orjun Loskor	Green Khira
Bottle gourd	Sobuj Bangla	Afzal Hazari
Ash gourd	Anamika	Green Master

3.1.12. Data collection

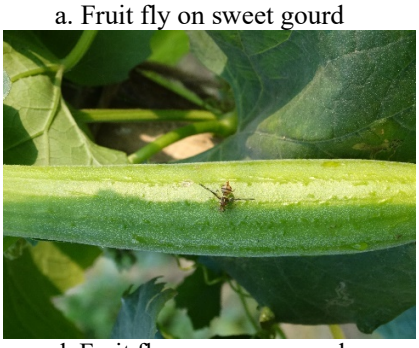
The data were collected from the flower initiation of cucurbits and continued up to last harvest of the fruits at seven (7) days interval. The following parameters were considered to find out the objectives of the experiment.

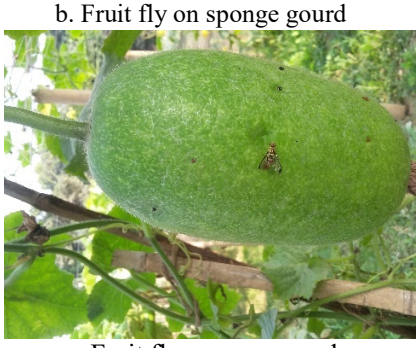
- **Number of total fruits per plot:** Number of total fruits per plot was counted by the harvesting of cucurbits per plot at 7 days interval. The data were recorded from the first harvest up to the last harvest of the cucurbit fruits. Different types of infested cucurbit fruits data were collected and recorded separately.
- **Number of infested fruits per plot:** Number of infested fruits per plot was counted by the harvesting of cucurbits per plot at 7 days interval. The data were recorded from the first harvest up to the last harvest of the cucurbit crops.

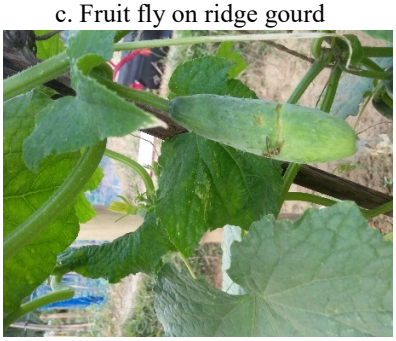

a. Fruit fly on sweet gourd

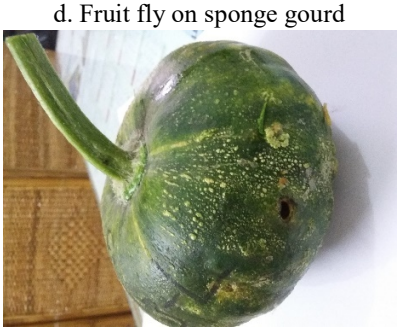

b. Fruit fly on sponge gourd

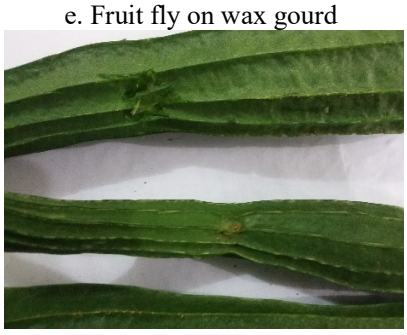

c. Fruit fly on ridge gourd


d. Fruit fly on sponge gourd


e. Fruit fly on wax gourd


f. Fruit fly on cucumber


g. Bore of fruit fly on sweet gourd


h. Infested and deformed ridge gourd

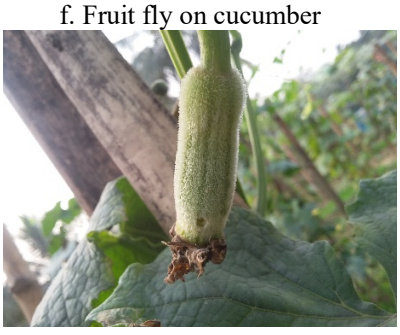

i. Infested sponge gourd

Plate 6. Different cucurbit fruits infested by cucurbit fruit fly

- **Weight of total fruits per plot:** Weight of total fruits per plot was measured with the help of digital measuring scale at 7 days interval. The data were recorded from the first harvest to the last harvest of cucurbit fruits and recorded separately. Similarly data on the weight of healthy and infested cucurbit fruits per plot were recorded separately.
- **Length of healthy and infested fruits:** Length of healthy and infested cucurbit fruits were measured through measuring tape and recorded separately.
- **Girth of healthy and infested fruits:** Girth of healthy and infested cucurbit fruits were measured through measuring tape and recorded separately.

Plate 7. Data collection

- **Number of bore/infestation symptom per fruit:** After isolating different infested cucurbit fruits were closely observed and number of bore and infestation symptom were counted and recorded separately.
- **Weight of edible portion of infested fruits:** Infested cucurbit fruits were cut into pieces by knives and edible portion was separated weighed and recorded separately.
- **Weight of damaged portion of infested fruits:** Infested cucurbit fruits were cut into pieces by knives and damaged portion was separated,weighed and recorded separately.

3.1.13. Data calculation

Fruit infestation(number)

Number of infested fruits was counted per plot and percent fruit infestation by were calculated as follows:

% Infestation of fruit {number) = $\frac{Number\ of\ infested\ fruits}{Total\ number\ of\ fruits} \times 100$

Fruit infestation (weight)

Weight of infested fruits was measured per plot and percent fruit infestation by weight by fruit fly of cucurbit were calculated as follows:

% Infestation of fruits (weight) = $\frac{Weight\ of\ infested\ fruits}{Total\ wei \quad of\ fruits} \times 100$

3.1.14. Statistical analysis

Data were analyzed by using MSTAT software for analysis of variance after square root transformation. ANOVA was made by F variance test and the pair comparisons were performed by Duncan Multiple Range Test (DMRT).

3.2. Experiment 2: Study on the bio-ecology of cucurbit fruit fly while infesting cucurbitaceous vegetables

3.2.1. Objectives

1. To know the biology of cucurbit fruit fly reared on most preferred cucurbits;

2. To realize the effect of weather variations on the growth and development of cucurbit fruit fly;

3. To find out the relationship in between the life cycle of cucurbit fruit fly and weather factors.

The materials and methods those were used and followed for conducting the experiment have been presented under the following headings:

3.2.2. Location

The experimental site was located at the central laboratory, Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka-1207, during the period of July, 2017 to June, 2018.

3.2.3. Time duration of the study

The study was conducted during the year round (both Rabi and Kharif season). Laboratory experiment was set up at first week of July 2017 and ended at last week of June 2018.

3.2.4. Materials used and mass culture of cucurbit fruit fly

Cucurbit fruit fly infested bitter gourds were collected from the local market. Then larvae were collected from these infested bitter gourds and reared in rearing cases with fresh bitter gourd fruits. For mass culture only need to maintain fruit fly providing food in insect cage.

3.2.5. Design

The experiment was laid out in Complete Randomized Design (CRD) with 10 replication for evaluating the life cycle of cucurbit fruit fly on bitter gourd. The whole study was done in the laboratory where the temperature (25ºC) and relative humidity (80%) were strictly maintained.

3.2.6. Species identification

Before setting the experiment the collected fruit fly was identified at species level according to the basis of traditional taxonomy (White and Elson-Harris 1994, Foote and Blanc 1963).

3.2.7. Genitalia examination

The genitalia examination was done for species identification by following the method of Hardy (1949).

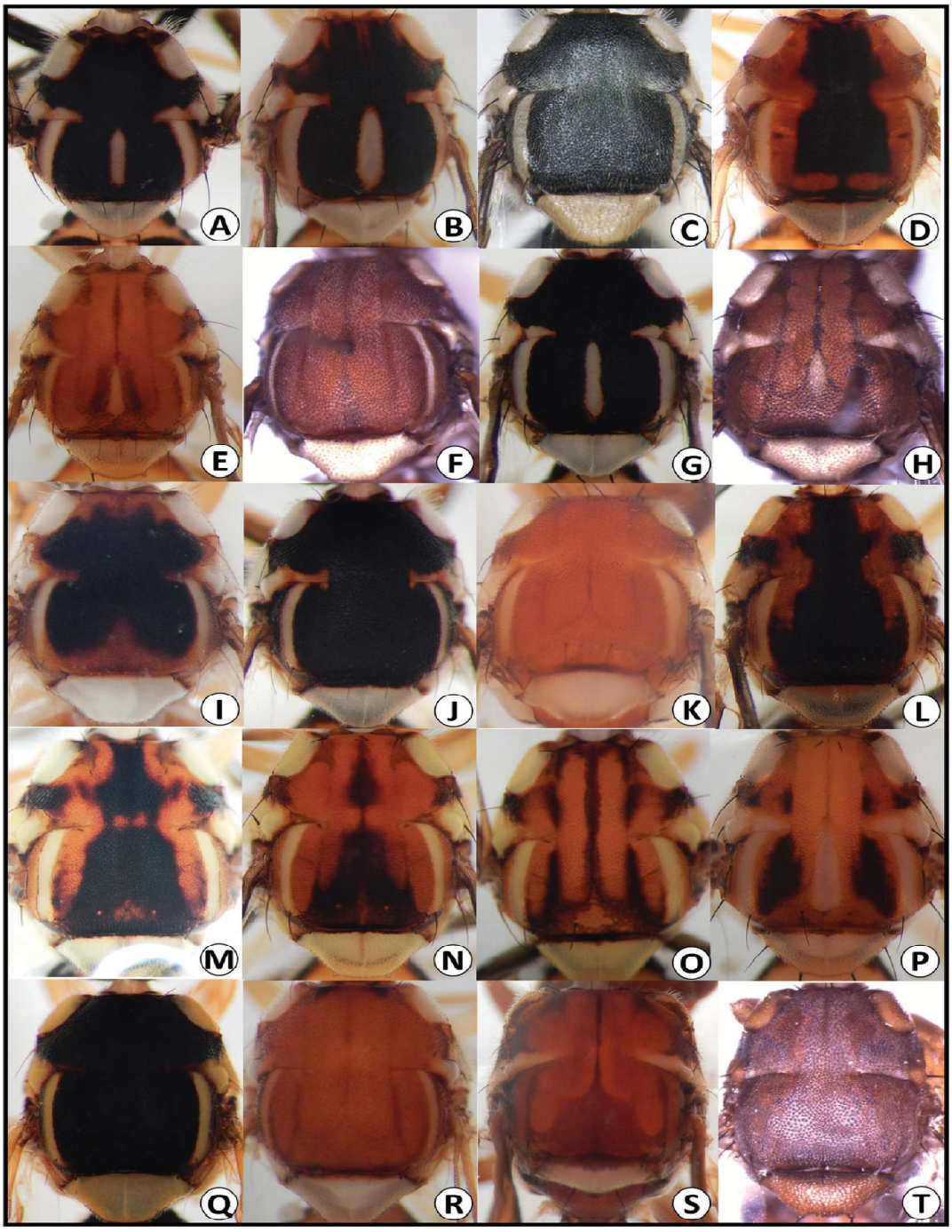


Plate 8. Scutum color patterns for *Bactrocera bogorensis* (A), *B. caudata* (B), *B. cilifera* (C), *B. correcta* (D), *B. cucurbitae* (E), *B. digressa* (F), *B. diversa* (G), *B. hochii* (H), *B. latifrons* (I), *B. nigrifacia* (J), *B. rubigina* (K), *B.* species 45 (L,M,N), *B.* sp. (possibly *B. bhutaniae*) (O), *B. tau* (P), *B. tuberculata* (Q), *B. zonata* (R), *Dacus longicornis* (S), and *D. ciliatus* (T) (Leblane *et al. 2014*)

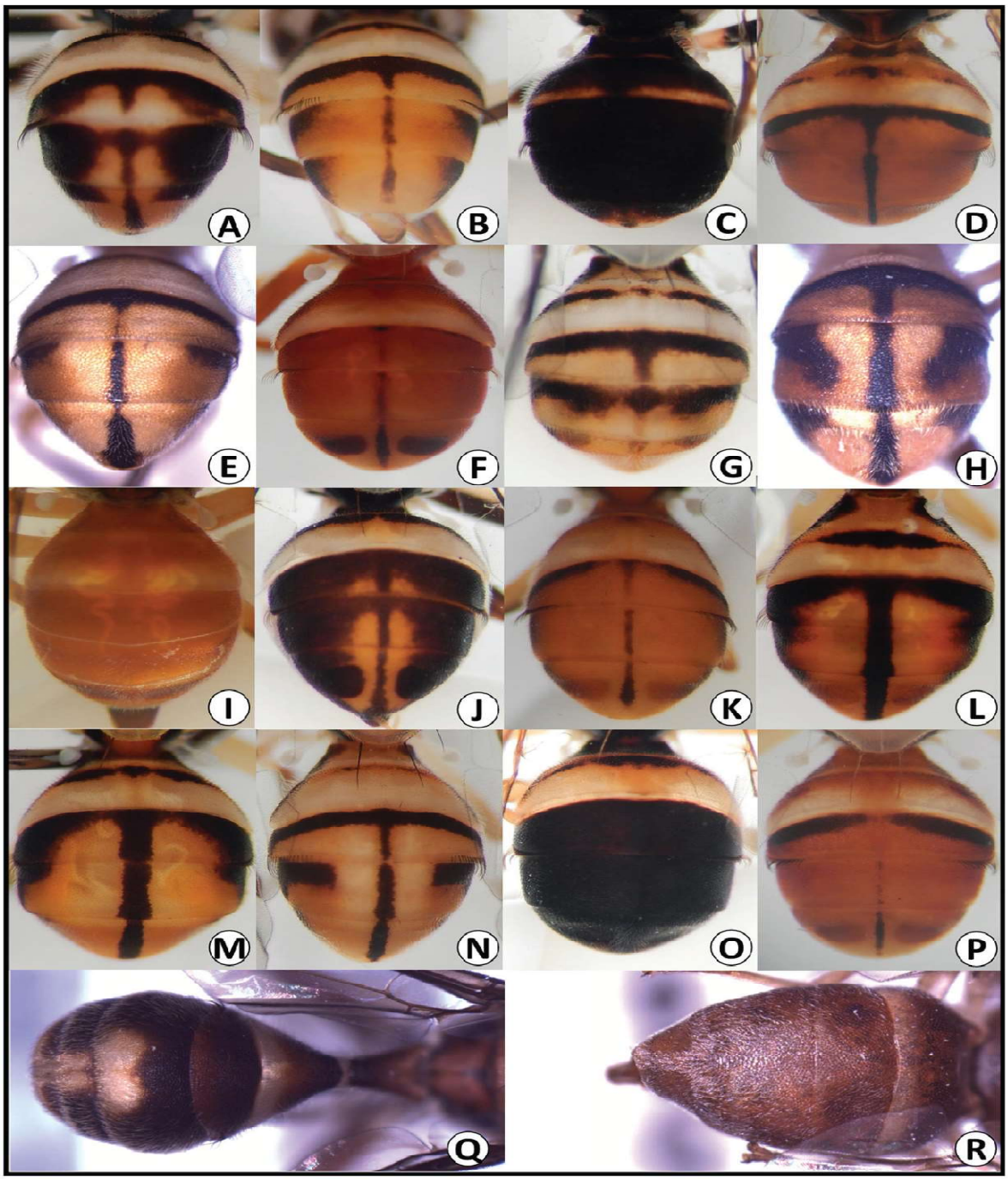


Plate 9. Abdomen color patterns for *Bactrocera bogorensis* (A), *B. caudata* (B), *B. cilifera* (C), *B. correcta* (D), *B. cucurbitae* (E), *B. digressa* (F), *B. diversa* (G), *B. hochii* (H), *B. latifrons* (I), *B. nigrifacia* (J), *B. rubigina* (K), *B.* species 45 (L), *B*. sp. (possibly *B. bhutaniae*) (M), *B. tau* (N), *B. tuberculata* (O), *B. zonata* (P), *Dacus longicornis* (Q), and *D. ciliatus* (R) (Leblane *et al. 2014*)

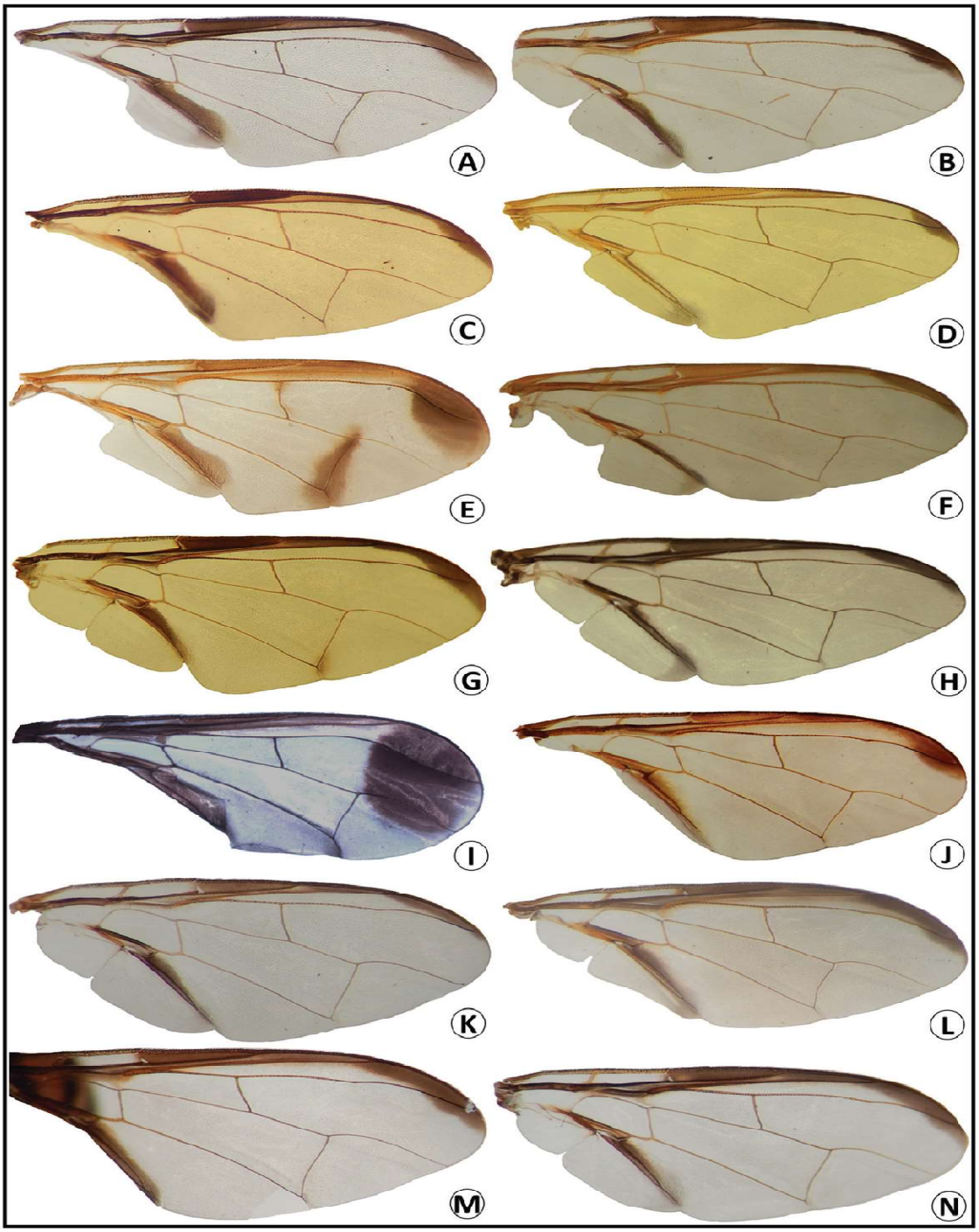


Plate 10. Wings of *Bactrocera bogorensis* (A), *B. caudata* (B), *B. cilifera* (C), *B. correcta* (D), *B. cucurbitae* (E), *B. digressa* (F), *B. diversa* (G), *B. dorsalis* (H), *B. hochii* (I), *B. latifrons* (J), *B. nigrifacia* (K), *B. rubigina* (L), *B.* species 45 (M), *B.* sp. (possibly *B. bhutaniae*) (N) (Leblane *et al. 2014*)

3.2.8. Biology study of cucurbit fruit fly

Newly emerged adult fruit flies were sexed and confined in pairs for egg laying in petridishes supplied with fresh bitter gourdsin everyday morning. Ten replications were maintained. Eggs were separated from the infested fruits and newly hatched larvae were transferred individually. Incubation, number of instars and duration, pupation, oviposition and fecundity were observed twice daily.

3.2.9. Data collection perimeter

Close observation was done to record the data on egg laying period by the adult female, number of eggs lay per fruit, incubation period, larval period, pupal period, number of adult emergence per fruit, sex ratio among adult emerged, adult longevity as well as daily temperature and relative humidity in the laboratory. The parameters have been illustrated as follows:

3.2.9.1. Egg laying period: Ten newly emerged male and female adults were taken from the mass culture and kept them in petridishes for egg laying. Three replications were maintained and closely observed daily and recorded the egg laying period.

Plate 11. Eggs of cucurbit fruit fly

3.2.9.2. Incubation period: Hatching of larvae from egg was observed for recording at 10 am every day. This experiment was started with keeping one newly infested bitter gourd in a petridish and were ended with hatching of larva. A simple microscope with light source, petridish and needle were used to perform this experiment.

3.2.9.3. Larval period: Fresh bitter gourd was supplied to every petridishes for feeding of newly hatched larvae. Thirty replications were maintaind for observed the parameter.

3.2.9.4. Pupal period: Closely observed 4th instar larvae when transformed into pupa, then pupe were collected and separately kept into petridishes individually. The pupae were observed daily and up to adult formation.

Plate 12. Maggots of cucurbit fruit fly

Plate 13. Pupa of cucurbit fruit fly both cluster and single (microscopic) formation

3.2.9.5. Adult longevity: At the completion of pupal stage, emergence of adults were occurred in the petridishes. Twenty adults were randomly collected from petridishes and kept in a test tube, and the open end of the test tube was tied with fine meshed net for aeration. Data of adult longevity,fecundity and mortality were recorded.

a. Adult male

b. Adult female

Plate 14. Adult (both male and female) cucurbit fruit fly

3.2.9.6. Ambient temperature and relative humidity: Ambient temperature and relative humidity inside the laboratory room were recorded using thermometer and hygrometer.

3.2.10. Data analysis

Data were analyzed following the analysis of variance (ANOVA) technique with the help of MSTAT-C software/statistical program and the mean differences was adjusted by Least Significant Difference (LSD) technique.

3.2. Experiment 2: Study on the bio-ecology of cucurbit fruit fly while infesting cucurbitaceous vegetables

3.2.1. Objectives

1. To know the biology of cucurbit fruit fly reared on most preferred cucurbits;

2. To realize the effect of weather variations on the growth and development of cucurbit fruit fly;

3. To find out the relationship in between the life cycle of cucurbit fruit fly and weather factors.

The materials and methods those were used and followed for conducting the experiment have been presented under the following headings:

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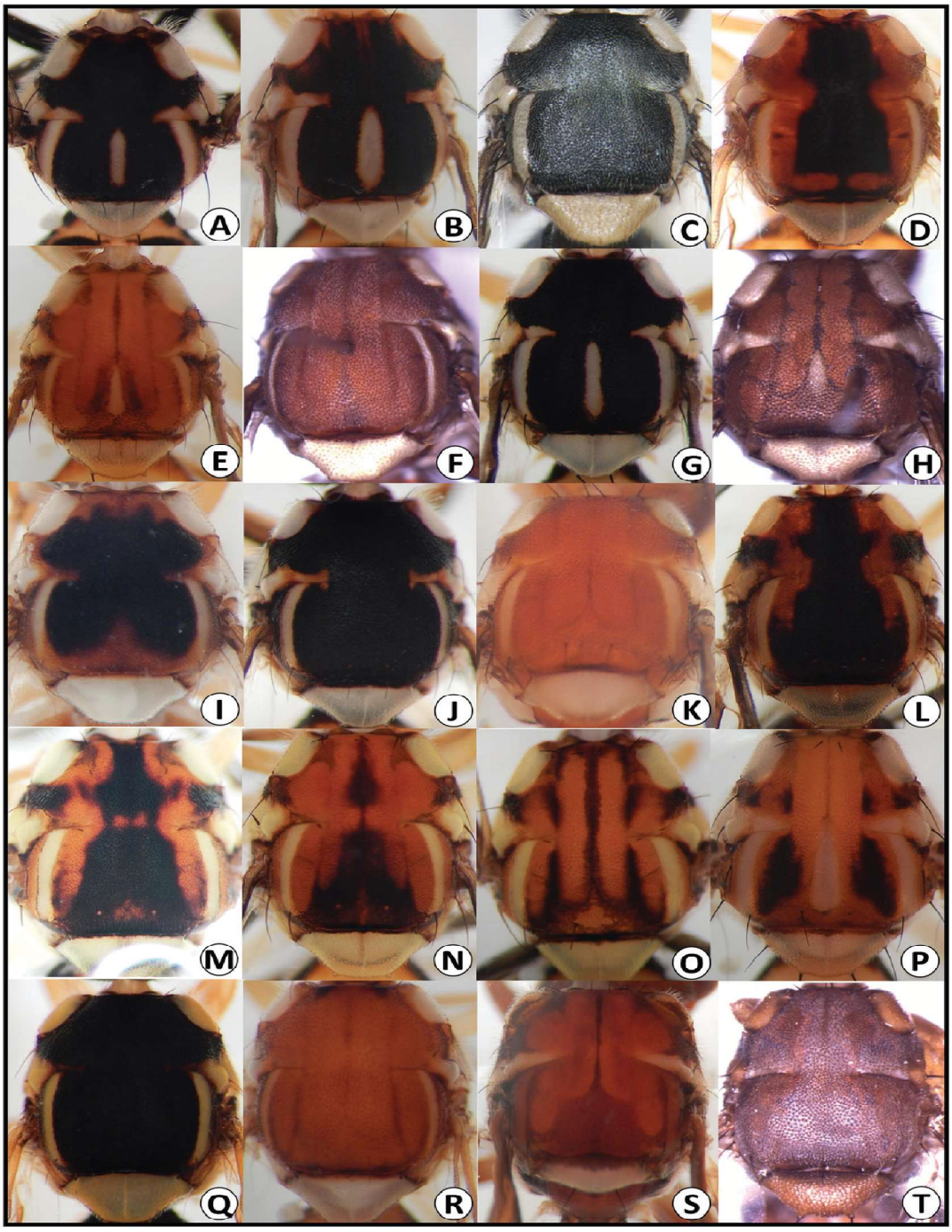

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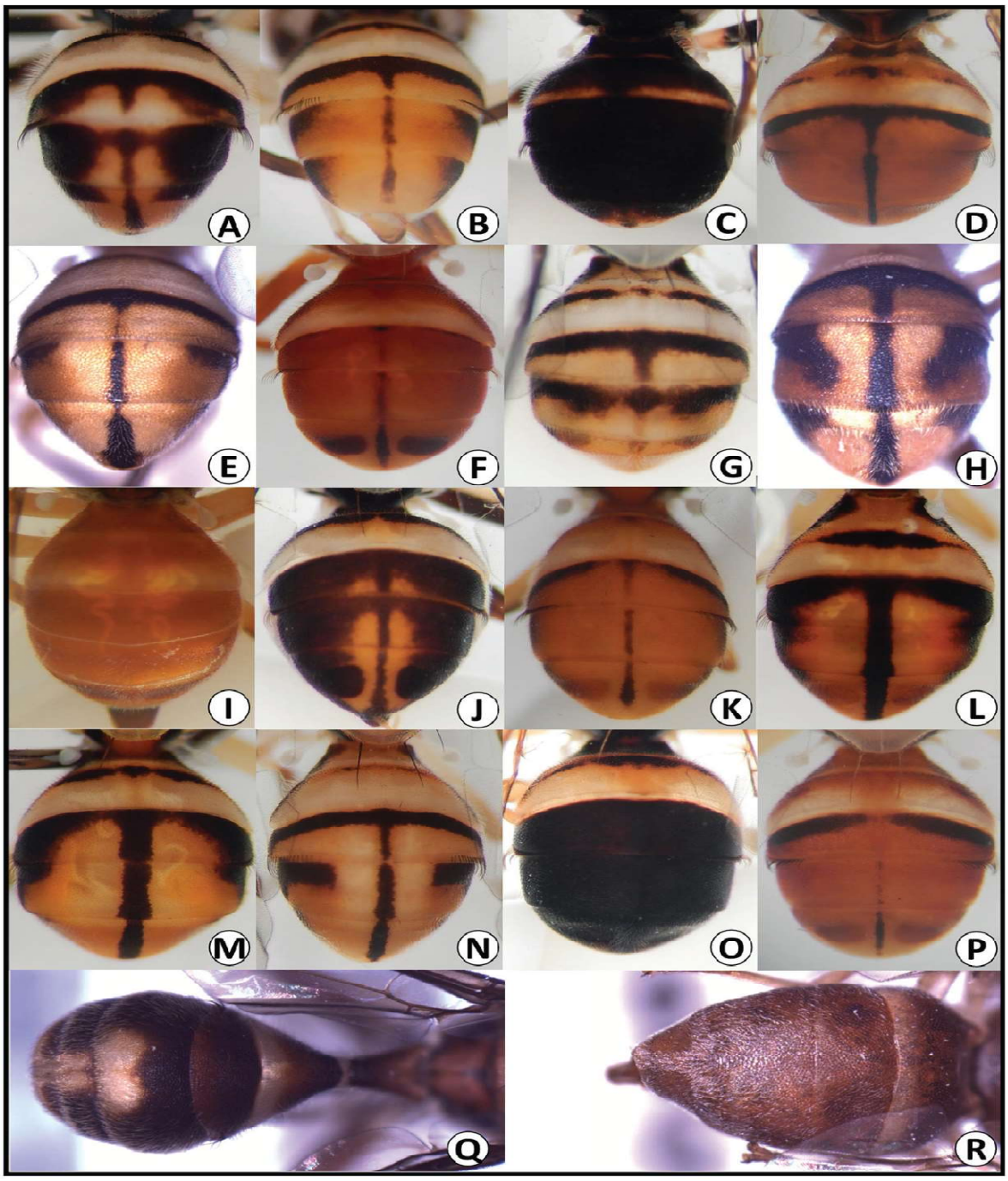

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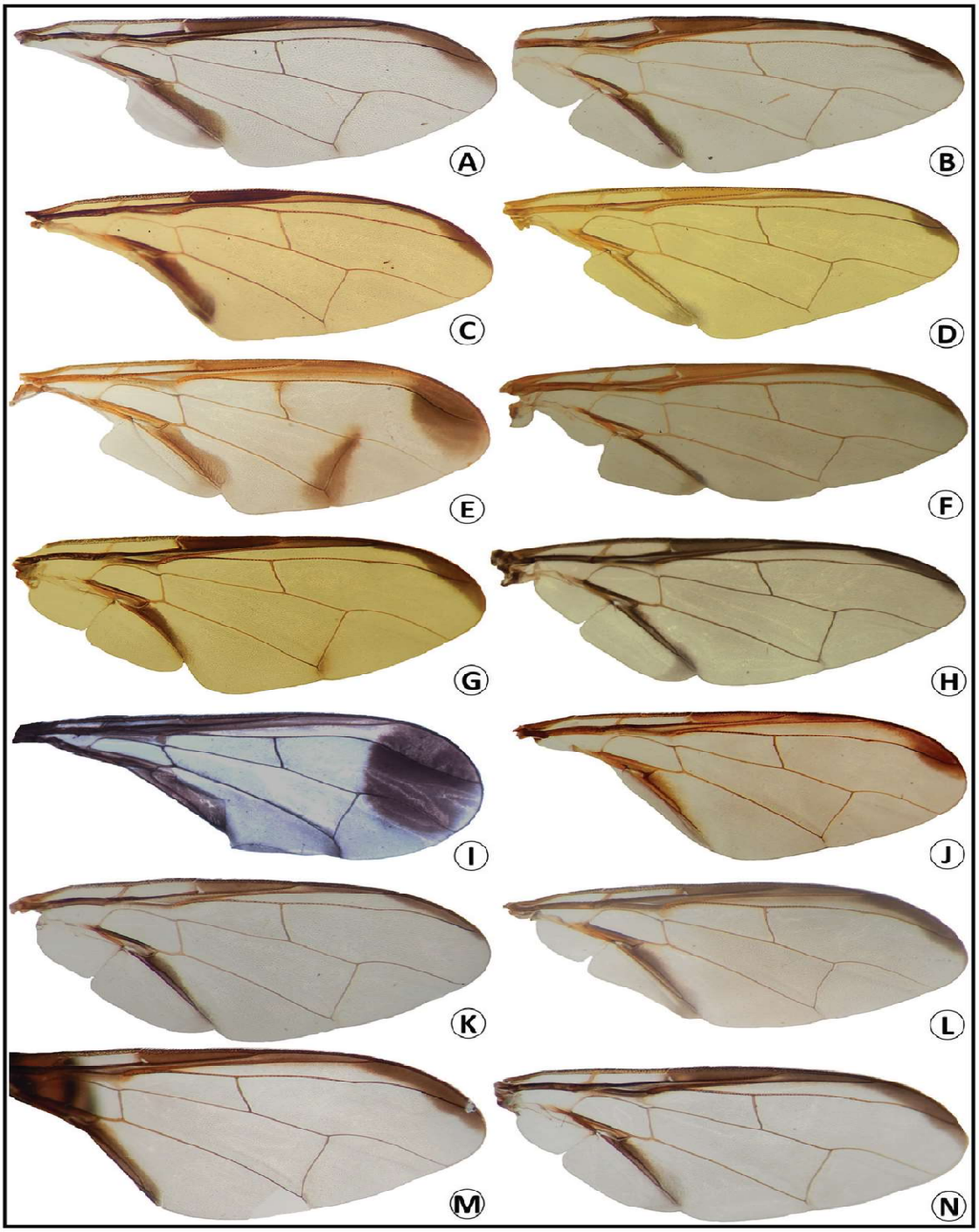

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3.2.8. Biology study of cucurbit fruit fly

Newly emerged adult fruit flies were sexed and confined in pairs for egg laying in petridishes supplied with fresh bitter gourdsin everyday morning. Ten replications were maintained. Eggs were separated from the infested fruits and newly hatched larvae were transferred individually. Incubation, number of instars and duration, pupation, oviposition and fecundity were observed twice daily.

3.2.9. Data collection perimeter

Close observation was done to record the data on egg laying period by the adult female, number of eggs lay per fruit, incubation period, larval period, pupal period, number of adult emergence per fruit, sex ratio among adult emerged, adult longevity as well as daily temperature and relative humidity in the laboratory. The parameters have been illustrated as follows:

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Plate 11. Eggs of cucurbit fruit fly

3.2.9.2. Incubation period: Hatching of larvae from egg was observed for recording at 10 am every day. This experiment was started with keeping one newly infested bitter gourd in a petridish and were ended with hatching of larva. A simple microscope with light source, petridish and needle were used to perform this experiment.

3.2.9.3. Larval period: Fresh bitter gourd was supplied to every petridishes for feeding of newly hatched larvae. Thirty replications were maintaind for observed the parameter.

3.2.9.4. Pupal period: Closely observed 4th instar larvae when transformed into pupa, then pupe were collected and separately kept into petridishes individually. The pupae were observed daily and up to adult formation.

Plate 12. Maggots of cucurbit fruit fly

Plate 13. Pupa of cucurbit fruit fly both cluster and single (microscopic) formation

3.2.9.5. Adult longevity: At the completion of pupal stage, emergence of adults were occurred in the petridishes. Twenty adults were randomly collected from petridishes and kept in a test tube, and the open end of the test tube was tied with fine meshed net for aeration. Data of adult longevity,fecundity and mortality were recorded.

a. Adult male

b. Adult female

Plate 14. Adult (both male and female) cucurbit fruit fly

3.2.9.6. Ambient temperature and relative humidity: Ambient temperature and relative humidity inside the laboratory room were recorded using thermometer and hygrometer.

3.2.10. Data analysis

Data were analyzed following the analysis of variance (ANOVA) technique with the help of MSTAT-C software/statistical program and the mean differences was adjusted by Least Significant Difference (LSD) technique.

3.3. Experiment 3: Evaluation of the efficacy of management practices along with bio-pesticides against cucurbit fruit fly

3.3.1. Objectives

1. To evaluate different management practices along with bio-pesticides for combating cucurbit fruit fly
2. To find out the effective and eco-friendly management practices of cucurbit fruit fly.

The materials and methods adopted in this study are discussed in the following sub headings:

3.3.2. Location

The experimental site was located at the experimental farm of SAU, Dhaka-1207. The experimental field was located at 90°33''5' east longitude and 23° 77''4' North latitude at a height of 4 meter above the sea level. The land was medium high and well drained.

3.3.3. Climate

The experimental site was situated in the sub-tropical climatic zone, characterized by lower rainfall during the month of April, 2017 to August, 2018. Monthly maximum and minimum temperature, relative humidity and total rainfall recorded during the period of study at the SAU experimental farm have been presented in the Appendix. Monthly average temperature, relative humidity and rainfall for the crop growing period of experiment were noted from the Bangladesh Meteorological Department (Climate Division), Agargaon, Dhaka-1207 and has been presented.

3.3.4. Soil

The soil of the study area was silty clay in texture. The area represents the Agroecological Zone of "Madhupur Tract" (AEZ No. 28). Organic matter content was very low (0.82%) and soil pH ranged from 5.47 to 5.63.

3.3.5. Design and layout

The study was conducted considering eight treatments including a control for controlling cucurbit fruit fly at seedling to harvesting stage. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications in the field of the Entomology Department. The whole field was divided three blocks of equal size and each block was sub divided into nine plots. The unit plot size was 2m × 1.5m accommodating twelve pits per plot. There were two pits at each plot.

3.3.6. Land preparation

The soil of the experimental field was well prepared thoroughly followed by plowing and cross plowing, leveling and laddering to have a good tilth. All weeds and debris of previous crops were removed and land was finally prepared with the addition of basal dose of well decomposed cow dung. The plots were raised by 10 cm from the soil surface keeping the drain around the plots.

3.3.7. Manuring and fertilization

The doses of manure and fertilizers was showed in chapter 3.1.7.

Plate 15. Experimental field

3.3.8. Material used and sowing

Bitter gourd seeds [Vatiety: Mehoman (Local variety)], marketed by ACI, were used for this experiment. Seeds were sown directly at the field. The plots were lightly irrigated regularly for ensuring germinationand proper development of the seedlings.

3.3.9. Intercultural operations

3.3.9.1. Thinning

Four seeds were sown in each pit. After ten days of sowing only two healthy seedlings in each pit were kept for the study and remains were thinned out from the experimental plot.

Plate 16. Main field after thining

3.3.9.2 Irrigation

After thinning light irrigation was given to each plot. Supplementary irrigation was applied at an interval of 2-3 days. Stagnant water was effectively drained out at the time of over irrigation. The urea was top dressed in three splits as mentioned earlier.

3.3.9.3 Weeding

Weeding was done as and when necessary to break the soil crust and to keep the plots free from weeds. First weeding was done after 20 days of sowing and the rests were out at an interval of 15 days to keep the plot free from weeds.

3.3.9.4 Earthing up

Earthing up was done in each plot to provide more soil at the base of each plant. It was done 40 and 60 days after transplanting.

3.3.10. Treatments for control measures

The botanical based treatments as well as their doses were used in the study are given below:

Table 3.3.1. List of the treatments

Treatments	Name of the treatments	Dose
T_1	Pheromone trap	1 trap per plot
T_2	Poison bait trap with carbaryl	1 trap per plot
T_3	Bait spray with malathion	2.5 ml/L of water at 7 days interval
T_4	Spinosad spray	0.08 ml/L of water at 7 days interval
T_5	Neem oil spray	3.0 ml/L of water at 7 days interval
T_6	Neem seed kernel extract spray	3.0 ml/L of water at 7 days interval
T_7	Malathion 57 EC Spray	1.0 ml/L of water at 7 days interval
T_8	Untreated control	

3.3.11. Treatment preparation

3.3.11.1. Pheromone trap

Sex pheromone trap designed by BARI with cue-lure [Hydrolyzed to Raspberry Ketone (RK)] and soapy water, were used to conduct this experiment. The traps were hung up under bamboo scaffold, 60 cm above the ground. The soap water was replaced by new soap water at an interval of 5 days.

a. Sex pheromone trap in the field

b. Fruit flies captured in the sex pheromone trap

Plate 17. Sex pheromone trap with captured fruit flies

3.3.11.2. Poison bait trap

The poison bait trap was consisted of 1g Sevin 85 SP (carbaryl), mixed with l00 g of mashed sweetgourd and 10 ml molasses. The bait was kept in a small earthen pot placed within a four splitted bamboo sticks, 50 cm above the ground. An earthen cover plate was placed 20 cm above the bait container to protect the bait material from sun and rain.

a. Poison bait trap in the experimental filed b. Fruit flies captured in the poison bait trap

Plate 18: Poison bait trap with captured fruit flies

3.3.11.3. Bait spray

The bait was prepared by mixing molasses and Malathion 57 EC with water in the proportion of 1: 0.1: 100. For the purpose of this study the bait spray was prepared by mixing 25g of molasses, 2.5 ml of Malathion 57 EC and 2.51 liter of water. This bait spray was applied uniformly on the selected plots and obtained complete coverage. The molasses attracted the fruit flies and Malathion 57 EC acted as systemic as well as contact poison. Caution was taken to avoid drift in other treated and control plots. The bait spray was applied at 7 days interval.

3.3.11.4. Spinosad

Spinosad was sprayed @ 0.08 ml per liter of water. It was sprayed at the foliage of the plant.

3.3.11.5. Neem oil

For each neem oil application, 15 ml neem oil @ 3.0 ml/L of water i.e. 0.3% per 5 liter of water was used. The mixture within the spray machine was shacked well and sprayed on the upper and lower surface of the plants of the treatment until the drop run off from the plant. Three liters spray material was required to spray in three plot of each replication.

3.3.11.6. Neem seed kernel

The mature and dried neem seeds were collected from the neem tree found in the Horticulture garden of SAU. Then seeds were roasted by electric oven. Then the seed kernel was separated and taken into the electric blender for blending. 250 gm of neem seed kernel powder was taken into a beaker and 250 ml water was added into the beaker. Then the beaker was shaken by electric stirrer for mixing up thoroughly the mixture. The aqueous mixture then filtered using Whatmen paper filter and preserved the aqueous extracts of neem seed kernel in the refrigerator at 4^0c for spraying in the field.

3.3.12. Treatment application

T_1: Sex pheromone trap was used one for a plot for one month. The soapy water was replaced by new soap water at an interval of five days commencing from 45 DAT.

T_2: One Poison bait trap was used for a plot. The old bait materials were changed and fresh ones were placed there for further use at an interval of five days commencing from 45 DAT.

T_3: Bait spray @ 2.5 ml/L of water was sprayed at 7 days interval. Under this treatment, Malathion 57 EC was applied @ 7.5 ml /3L of water mixed with molases @ 75 ml. After proper shaking, the prepared spray was applied with a high volume knap-sack sprayer at 7 days intervals commencing from 20 DAT.

T_4: Spinosad @ 0.08 ml/L of water was sprayed at 7 days interval. Under this treatment, spinosad was applied @ 0.24 ml /3L of water. After proper shaking, the prepared spray was applied with a high volume knap-sack sprayer at 7 days intervals commencing from 20 DAT.

T_5: Neem oil @ 3.0 ml/L of water was sprayed at 7 days interval. Under this treatment, neem oil was applied @ 9 ml /3L of water mixed with trix liquid detergent @ 10 ml (1%) to make the oil easy soluble in water. After proper shaking, the prepared spray was applied with a high volume knap-sack sprayer at 7 days intervals commencing from 20 DAT.

T_6: Neem seed kernel extract @ 3.0 ml/L of water was sprayed at 7 days. Under this treatment, neem seed kernel extract was applied @ 9 ml /3L of water. After proper shaking, the prepared spray was applied with a high volume knap-sack sprayer at 7 days intervals commencing from 20 DAT.

T_7: Malathion 57 EC @ 1.0 ml/L of water was sprayed at 7 days interval. For this treatment 3.0 ml of insecticides per 3 liter of water was mixed and sprayed at 7 days intervals commencing from 20 DAT.

T_8: Untreated control. There was no any control measure was applied in bitter gourd field.

3.3.13. Data collection

The data collection was started just before application of treatment and after spray 7 days interval on the following parameters:

- **Total number of fruits:** For the estimation of total number of fruits per plot, fruits were randomly selected and counted from each plot, at each time of data collection.
- **Number of infested fruits:** For the estimation of number of infested fruits per plot, fruits were randomly selected and counted from each plot, at each time of data collection.

a. Healthy fruit

b. Infested fruit

Plate 19. Healthy and infested fruits of bitter gourd

- **Total weight of fruits:** For the estimation of total weight of fruits per plot, fruits were randomly selected and weight was recorded, from each plot, at each time of data collection.
- **Weight of infested fruits:** For the estimation of weight of infested fruits per plot, fruits were randomly selected and weight recorded, from each plot, at each time of data collection.
- **Weight of edible portion of the infested fruits:** For the estimation of weight of edible portion of the infested fruits per plot, the infested fruits are collected and weight of edible portion recorded.
- **Length of healthy and infested fruits:** For the estimation of length of 10 randomly selected healthy and infested fruits per plot, fruits were randomly selected and length recorded, from each plot, at each time of data collection.
- **Girth of healthy and infested fruits:** For the estimation of girth of 10 randomly selected healthy and infested fruits per plot, fruits were randomly selected and girth recorded, from each plot, at each time of data collection.

- **Weight of fruits:** For the estimation of weight of 10 randomly selected fruits per plot, 10 fruits were randomly selected and weight recorded, from each plot, at each time of data collection.
- **Yield of fruits:** For the estimation of yield per plot total fruits were collected and weight recorded, from each plot, at each time of data collection.
- **Data on economic analysis:** The data were also recorded on cost of cultivation, cost of management practices and market price of fruit (Tk/kg).

The percent fruit infestation by number was calculated by the following procedure:

The formula to calculate the percent fruit infestation by number by cucurbit fruit fly was shown in chapter 3.1.13.

The percent fruit infestation by weight was calculated by the following procedure:

The formula to calculate the percent fruit infestation by weight by cucurbit fruit fly was shown in chapter 3.1.13.

Percent reduction of bitter gourd infestation over control

The formula to calculate the percent reduction of bitter gourd infestation over control was given below:

$$\% \text{ Reduction of bitter gourd infestation over control} = \frac{x_2 - x_1}{x_2} \times 100$$

Where x_2= the mean value of the treated plot

x_2 = the mean value of the untreated plot

3.3.14. Economic analysis of the treatment

Economic analysis in terms of benefit cost ratio (BCR) was analyzed on the basis of total expenditure of the respective management practices along with the total return from that particular treatment. In this study BCR was calculated for a hectare of land.

3.3.14.1. Treatment wise management cost/variable cost

This cost was calculated by adding all costs incurred for labours and inputs for each management treatment including untreated control during the entire cropping season. The plot yield (kg/plot) of each treatment was converted into ton/ha yield.

3.3.14.2. Gross Return (GR)

The yield in terms of money that was measured by multiplying the total yield by the unit price of bitter gourd (Tk 40/kg).

3.3.14.3. Net Return (NR)

The Net Return was calculated by subtracting treatment wise management cost from gross return.

3.3.14.4. Adjusted Net Return (ANR) and Benefit Cost Ratio (BCR)

The ANR was determined by subtracting the net return for a particular management treatment from the net return with control plot. Finally, BCR for each management treatment was calculated by using the following formula:

$$\text{Benefit cost ratio (BCR)} = \frac{\text{Adjusted net return}}{\text{Total management cost}}$$

3.3.15. Statistical analysis

Data were analyzed by using MSTAT software for analysis of variance after square root transformation. ANOVA was made by F variance test and the pair comparisons were performed by Duncan's Multiple Range Test (DMRT).

Experiment 4: Development of Integrated Pest Management (IPM) approach for combating cucurbit fruit fly

3.4.1. Objectives

1. To integrate the best possible combinations of the effective tools identified from the previous experiment as effective for developing effective integrated fruit fly management package on bitter gourd.

The materials and methods adopted in this study are discussed in the following sub headings:

3.4.2. Location

The experimental site was located at the experimental farm of SAU, Dhaka-1207, during the period from February, 2018 to June, 2018. The experimental field was located at 90°335' east longitude and 23°774' North latitude at a height of 4 meter above the sea level. The land was medium high and well drained.

3.4.3. Climate

The experimental site was situated in the sub-tropical climatic zone, characterized by lower rainfall during the month of February, 2018 to June, 2018. Monthly maximum and minimum temperature, relative humidity and total rainfall recorded during the period of study at the SAU experimental farm have been presented in the Appendix I. Monthly average temperature, relative humidity and rainfall for the crop growing period of experiment were noted from the Bangladesh meteorological Department (climate division), Agargaon, Dhaka-1207 and has been presented.

3.4.4. Soil

The soil of the study was silty clay in texture. The area represents the agroecological zone of "Madhupur tract" (AEZ No. 28). Organic matter content was very low (0.82%) and soil pH varied from 5.47 to 5.63.

3.4.5. Design and layout

The study was conducted considering ten treatments including a control for controlling cucurbit fruit fly at seedling to harvesting stage. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications in the field of the Entomology Department. The whole field was divided into three blocks of equal size and each block was sub divided into ten plots. The unit plot size was 2m × 1.5m. There were two pits at each plot.

3.4.6. Land preparation

The soil of the experimental field was well prepared thoroughly followed by plowing and cross plowing, leveling and laddering to have a good tilth. All weeds and debris of previous crops were removed and land was finally prepared with the addition of basal dose of well decomposed cow dung. The plots were raised by 10 cm from the soil surface keeping the drain around the plots.

3.4.7. Manuring and fertilization

The doses of manure and fertilizers was shown in chapter 3.1.7.

3.4.8. Materials used and sowing

Bitter gourd seeds (Vatiety: Tia (Hybrid variety)), marketed by Lal Teer, were used for this experiment. The pits were mulched for ensuring proper seed germination, proper growth and development of the seedlings. The 30 days old seedlings were transplanted in the main field.

Plate 20. Seedlings in ploybag

3.4.9. Intercultural operations

3.4.9.1. Gap filling

At the time of transplanting few seedlings were transplanted in the border of the experimental plots for gap filling. Very few numbers of seedlings were damaged after transplanting and such

seedling were replaced by healthy seedlings from the same planted earlier on the border of the experiment plot. The seedlings were transplanted with a mass of soil roots to minimize the transplanting shock.

3.4.9.2. Irrigation

After thinning light irrigation was given to each plot. Supplementary irrigation was applied at an interval of 2-3 days. Stagnant water was effectively drained out at the time of over irrigation. The urea was top dressed in three splits as mentioned earlier.

3.4.9.3. Weeding

Weeding was done as and when necessary to break the soil crust and to keep the plots free from weeds. First weeding was done after 20 days of planting and the rest were carried out at an interval of 15 days to keep the plot free from weeds.

3.4.9.4. Earthing up

Earthing up was done in each plot to provide more soil at the base of each plant. It was done 40 and 60 days after transplanting.

3.4.10. Treatment for control measures

The experiment was evaluated to determine the the development of integrated pest management (IPM) approach for combating cucurbit fruit fly of bitter gourd. The IPM based packages were used in the study are given below:-

Package 1: Pheromone Trap + Poison Bait Trap at 7 days interval as routine treatment

Package 2: Pheromone Trap + Bait Spray at 7 days interval as routine treatment

Package 3: Pheromone Trap + Spraying of Neem oil at 7 days interval as routine treatment

Package 4: Pheromone Trap + Spraying of Spinosad at 7 days interval as routine treatment

Package 5: Pheromone Trap + Cultural Practice comprised of collection and destruction of infested and fallen fruits from the field

Package 6: Poison Bait Trap + Spraying of Neem oil at 7 days interval as routine treatment

Package 7: Poison Bait Trap + Spraying of Spinosad at 7 days interval as routine treatment

Package 8: Bait Spray + Spraying of Neem oil at 7 days interval as routine treatment

Package 9: Poison Bait Trap + Cultural Practice comprised of collection and destruction of infested and fallen fruits from the field

Package 10: Untreated control

3.4.11. Treatment preparation

3.4.11.1. Pheromone trap

Details of sex pheromone trap was given in chapter 3.3.11.1.

3.4.11.2. Poison bait trap

Details of poison bait trap was given in chapter 3.3.11.2.

3.4.11.3. Bait spray

Details of bait spray was given in chapter 3.3.11.3.

3.4.11.4. Spinosad

Details of spinosad spray was given in chapter 3.3.11.4.

3.4.11.5. Neem oil

Details of neem oil was given in chapter 3.3.11.5.

3.4.12. IPM Packages application

Package 1: Sex pheromone trap was used one for a plot for one month. The soap water was replaced by new soap water at an interval of five days commencing from 45 DAT. Poison bait trap was used one for a plot. The old bait materials were changed and

fresh ones were placed there for further use at an interval of five days commencing from 45 DAT.

Package 2: Sex pheromone trap was used one for a plot for one month. The soap water was replaced by new soap water at an interval of five days commencing from 45 DAT. Bait spray @ 2.5 ml/L of water was sprayed at 7 days interval. Under this treatment, Malathion 57 EC was applied @ 7.5 ml /3L of water mixed with molases @ 75 ml. After proper shaking, the prepared spray was applied with a high volume knap-sack sprayer at 7 days intervals commencing from 20 DAT.

Package 3: Sex pheromone trap was used one for a plot for one month. The soap water was replaced by new soap water at an interval of five days commencing from 45 DAT. Neem oil @ 3.0 ml/L of water was sprayed at 7 days interval. Under this treatment, neem oil was applied @ 9 ml /3L of water mixed with trix liquid detergent @ 10 ml (1%) to make the oil easy soluble in water. After proper shaking, the prepared spray was applied with a high volume knap-sack sprayer at 7 days intervals commencing from 20 DAT.

Package 4: Sex pheromone trap was used one for a plot for one month. The soap water was replaced by new soap water at an interval of five days commencing from 45 DAT. Spinosad @ 0.08 ml/L of water was sprayed at 7 days interval. Under this treatment, spinosad was applied @ 0.24 ml /3L of water. After proper shaking, the prepared spray was applied with a high volume knap-sack sprayer at 7 days intervals commencing from 20 DAT.

Package 5: Sex pheromone trap was used one for a plot for one month. The soap water was replaced by new soap water at an interval of five days commencing from 45 DAT.

Among cultural practices include field sanitation, irrigation, collection and destruction of infested and fallen fruits from the field were done at the seven days intervals commencing from 20 DAT.

Package 6: Poison bait trap was used one for a plot. The old bait materials were changed and fresh ones were placed there for further use at an interval of five days commencing from 45 DAT. Neem oil @ 3.0 ml/L of water was sprayed at 7 days interval. Under this treatment, neem oil was applied @ 9 ml /3L of water mixed with trix liquid detergent @ 10 ml (1%) to make the oil easy soluble in water. After proper shaking, the prepared spray was applied with a high volume knap-sack sprayer at 7 days intervals commencing from 20 DAT.

Package 7: Poison bait trap was used one for a plot. The old bait materials were changed and fresh ones were placed there for further use at an interval of five days commencing from 45 DAT. Spinosad @ 0.08 ml/L of water was sprayed at 7 days interval. Under this treatment, spinosad was applied @ 0.24 ml /3L of water. After proper shaking, the prepared spray was applied with a high volume knap-sack sprayer at 7 days intervals commencing from 20 DAT.

Package 8: Bait spray @ 2.5 ml/L of water was sprayed at 7 days interval. Under this treatment, Malathion 57 EC was applied @ 7.5 ml /3L of water mixed with molases @ 75 ml. After proper shaking, the prepared spray was applied with a high volume knap-sack sprayer at 7 days intervals commencing from 20 DAT. Neem oil @ 3.0 ml/L of water was sprayed at 7 days interval. Under this treatment, neem oil was applied @ 9 ml /3L of water mixed with trix liquid detergent @ 10 ml (1%) to make the oil easy

soluble in water. After proper shaking, the prepared spray was applied with a high volume knap-sack sprayer at 7 days intervals commencing from 20 DAT.

Package 9: Poison bait trap was used one for a plot. The old bait materials were changed and fresh ones were placed there for further use at an interval of five days commencing from 45 DAT. Among cultural practices include field sanitation, irrigation, collection and destruction of infested and fallen fruits from the field were done at the seven days intervals commencing from 20 DAT.

Package 10: Untreated control. There was no any control measure was applied in bitter gourd field.

3.4.13. Data collection

The data collection was started just before application of treatment at 7 days interval on the following parameters:

- **Total number of fruits:** For the estimation of total number of fruits per plot, fruits were randomly selected,labelled and counted from each plot at each time of data collection.
- **Number of infested fruits:** For the estimation of number of infested fruits per plot, fruits were randomlyselected,labelled and counted from each plot at each time of data collection.
- **Total weight of fruits:** For the estimation of total weight of fruits per plot, fruits were randomly selected and weight was recorded, from each plot at each time of data collection.
- **Weight of infested fruits:** For the estimation of weight of infested fruits per plot, fruits were randomly selected and weight recorded, from each plot at each time of data collection.

- **Weight of edible portion of the infested fruits:** For the estimation of weight of edible portion of the infested fruits per plot, the infested fruits are collected and weight of edible portion recorded.
- **Length of healthy and infested fruits:** For the estimation of length of 10 randomly selected healthy and infested fruits per plot, fruits were randomly selected and length recorded, from each plot, at each time of data collection.
- **Girth of healthy and infested fruits:** For the estimation of girth of 10 randomly selected healthy and infested fruits per plot, fruits were randomly selected and girth recorded, from each plot, at each time of data collection.
- **Weight of fruits:** For the estimation of weight 10 fruits per plot were selected randomly and recorded the weight at each time of data collection.
- **Yield of fruits:** For the estimation of yield per plot total fruits were collected and recorded the weight at each time of data collection.

Percent fruit infestation by number:

The formula to calculate the percent fruit infestation by number by cucurbit fruit fly was shown in chapter 3.1.11.

Percent fruit infestation by weight:

The formula to calculate the percent fruit infestation by weight by cucurbit fruit fly was shown in chapter 3.1.11.

Percent reduction of bitter gourd infestation over control

The formula to calculate the percent reduction of bitter gourd infestation over control was shown in chapter 3.3.13.

3.4.14. Statistical analysis

Data were analyzed by using MSTAT software for analysis of variance after square root transformation. ANOVA was made by F variance test and the pair comparisons were performed by Duncan's Multiple Range Test (DMRT).

CHAPTER IV

RESULTS AND DISCUSSION

Experiment 1: Study on the host preference and damage assessment of commonly cultivated cucurbitaceous vegetables against fruit fly

The results of the present study regarding the host preference and damage assessment of commonly cultivated cucurbitaceous vegetables against cucurbit fruit fly conducted in the experimental field of the Department of Entomology at SAU, Dhaka during March 2016 to July 2016 have been discussed and presented with interpretations under the following sub-headings:

4.1.1. Number of cucurbit fly

Kharif season: There was significantly variation among the number of cucurbit fruit fly at different growing stage which was shown in table 4.1.1. In case of early fruiting stage, the average number of cucurbit fruit fly in both local and hybrid variety was low in sweet gourd (2.19 and 2.46 flies) followed by ash gourd (2.83 and 3.62 flies), sponge gourd (3.16 and 4.33 flies),snake gourd (3.42 and 4.64 flies), ridge gourd (3.63 and 5.33 flies), bottle gourd (3.78 and 4.65 flies) and cucumber (5.13 and 5.79 flies). On the other hand, thehighest number of cucurbit fruit fly was observed in both local and hybrid variety of bitter gourd (4.47 and 6.56 flies). More or less similar trend was observed in mid and late fruiting stage of other cucurbitace crops.

The average number of cucurbit fruit fly was low in both local and hybrid variety of sweet gourd (2.56 and 3.07 flies) followed by ash gourd (3.42 and 4.37 flies), snake gourd (3.96 and 4.82 flies), sponge gourd (4.13 and 4.97 flies), bottle gourd (4.33 and 5.11 flies), cucumber (4.49 and 5.78 flies) and ridge gourd (4.76 and 6.31 flies). On the other hand, the average number of cucurbit fruit fly was high in both local and hybrid variety of bitter gourd (5.12 and 6.89 flies).

Table 4.1.1. Number of fruit flies on cucurbit crops at early, mid and late fruiting stage in kharif season

Varieties	Number of cucurbit fruit flies							
	Early fruiting stage		Mid fruiting stage		Late fruiting stage		Average	
	Local	Hybrid	Local	Hybrid	Local	Hybrid	Local	Hybrid
Cucumber	5.13 d	5.79 b	4.48 e	6.67 b	3.87 f	4.87 d	4.49 f	5.78 c
Ridge gourd	3.63 g	5.33 c	5.89 cd	7.56 a	4.76 d	6.03 ab	4.76 e	6.31 b
Snake gourd	3.42 h	4.11 f	4.64 e	5.67 d	3.82 f	4.67 d	3.96 hi	4.82 e
Sweet gourd	2.19 j	2.46 j	2.92 g	3.83 f	2.56 h	2.92 h	2.56 l	3.07 k
Sponge gourd	3.16 h	4.33 ef	5.12 de	5.71 d	4.11 e	4.87 d	4.13 h	4.97 de
Bitter gourd	4.47 e	6.56 a	5.98 c	7.98 a	4.92 d	6.13 a	5.12 d	6.89 a
Bottle gourd	3.78 g	4.65 e	4.98 e	5.56 d	4.23 e	5.12 c	4.33 fg	5.11 d
Ash gourd	2.83 i	3.62 g	4.03 f	5.23 d	3.41 g	4.26 e	3.42 j	4.37 f
CV (%)	3.87		4.21		3.14		2.56	
$LSD_{(0.05)}$	0.43		0.72		0.49		0.34	

From this above findings it was concluded that, the average number of cucurbit fruit flies incidence was high in hybrid cucurbit crops than local varieties. Again, bitter gourd was found most susceptible crop for cucurbit fruit fly infestation and sweet gourd was more resistant than others.

Rabi season: There was significantly variation among the number of cucurbit fruit fly at different growing stage which was shown in table 4.1.2. In case of early fruiting stage, the average number of cucurbit fruit fly in both local and hybrid variety was low in sweet gourd (2.76 and 4.57 flies) followed by ash gourd (3.83 and 5.32 flies), sponge gourd (3.71 and 5.29 flies),snake gourd (3.61 and 5.67 flies), cucumber (3.98 and 5.66 flies), bottle gourd (4.11 and 5.69 flies) and ridge gourd (4.78 and 6.12 flies). On the other hand, thehighest number of cucurbit fruit fly was observed in both local and hybrid variety of bitter gourd (4.78 and 5.89 flies). More or less similar trend was observed in mid and late fruiting stage of other cucurbitace crops.

The average number of cucurbit fruit fly was low in both local and hybrid variety of sweet gourd (3.21 and 5.19 flies) followed by ash gourd (4.19 and 5.47 flies), snake gourd (4.21 and 5.19 flies), sponge gourd (4.53 and 6.11 flies), bottle gourd (4.78 and 6.31 flies), cucumber (5.12 and

6.63flies) and ridge gourd (5.27 and 6.78 flies). On the other hand, the average number of cucurbit fruit fly was high in both local and hybrid variety of bitter gourd (5.89 and 7.03 flies).

Table 4.1.2. Number of fruit flies on cucurbit crops at early, mid and late fruiting stage in rabi season

Varieties	Number of cucurbit fruit flies							
	Early fruiting stage		Mid fruiting stage		Late fruiting stage		Average	
	Local	Hybrid	Local	Hybrid	Local	Hybrid	Local	Hybrid
Cucumber	3.98 c	5.66 a	6.15 c	7.67 a	5.23 c	6.56 b	5.12 c	6.63 b
Ridge gourd	4.78 b	6.12 a	5.89 c	7.67 a	5.14 c	6.56 b	5.27 c	6.78 ab
Snake gourd	3.61 cd	5.67 a	4.97 d	6.46 c	4.06 de	5.79 c	4.21 d	5.97 b
Sweet gourd	2.76 d	4.57 b	3.77 e	5.83 c	3.11 e	5.17 c	3.21 e	5.19 c
Sponge gourd	3.71 c	5.29 b	5.56 d	6.92 b	4.33 d	6.13 b	4.53 d	6.11 b
Bitter gourd	4.78 b	5.89 a	7.21 b	7.93 a	5.67 c	7.27 a	5.89 bc	7.03 a
Bottle gourd	4.11 c	5.69 a	5.72 c	6.94 b	4.51 d	6.29 b	4.78 d	6.31 b
Ash gourd	3.83 c	5.32 ab	4.67 de	5.67 c	4.07 de	5.41 c	4.19 d	5.47 c
CV (%)	1.34		0.89		1.16		0.98	
LSD $_{(0.05)}$	0.86		0.92		0.91		0.87	

From this above findings it was concluded that, the average number of cucurbit fruit flies incidence was high in hybrid cucurbit crops than local varieties. Again, bitter gourd was found most susceptible crop for cucurbit fruit fly infestation and sweet gourd was more resistant than others.

Comparison of fruit fly number observed in kharif and Rabi seasons

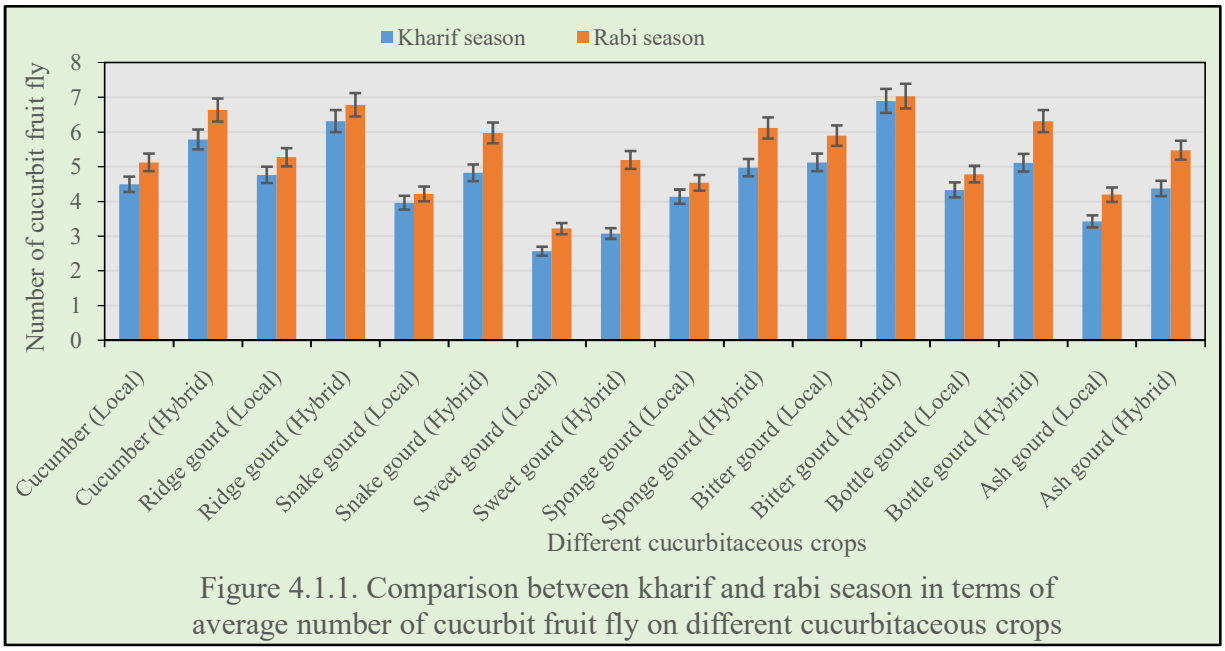

Figure 4.1.1. Comparison between kharif and rabi season in terms of average number of cucurbit fruit fly on different cucurbitaceous crops

From this above findings, it was revealed that, the average number of cucurbit fruit fly remain low in kharif season and high in rabi season. Besides this, highest number of cucurbit fruit fly was found in bitter gourd and lowest in sweet gourd. More or less researcher also conducted their experiments to identify the host range and fruit infestation rate. Among them Allwood *et al.* 2000 also explore the more or less similar result in case of fruit infestation by cucurbit fruit fly.

4.1.2. Percent fruit infestation (number) caused by fruit fly

Kharif season: There was significantly variation among the percent fruit infestation (number) caused by cucurbit fruit fly at different growing stage which was shown in table 4.1.3. In case of early fruiting stage, the average percentfruit infestation (number) caused by cucurbit fruit fly in both local and hybrid variety was low in sweet gourd (13.69% and 15.57%) followed by ash gourd (15.51% and 16.06%), sponge gourd (16.33% and 16.84%),snake gourd (14.68% and 14.13%), ridge gourd (20.22% and 32.23%), bottle gourd (16.46% and 17.78%) and cucumber (18.33% and 20.21%). On the other hand, thehighest number of cucurbit fruit fly was observed in both local and hybrid variety of bitter gourd (21.33% and 24.73%). More or less similar trend was observed in mid and late fruiting stage of other cucurbitace crops.

The average percent fruit infestation (number) caused by cucurbit fruit fly was low in both local and hybrid variety of sweet gourd (23.46% and 25.80%) followed by ash gourd (25.52% and 26.68%), snake gourd (27.40% and 28.97%), sponge gourd (30.03% and 31.29%), bottle gourd (31.45% and 32.98%), cucumber (33.89% and 35.30%) and ridge gourd (35.38% and 38.15%). On the other hand, the percent fruit infestation (number) caused by cucurbit fruit fly was high in both local and hybrid variety of bitter gourd (37.27% and 39.78%).

Table 4.1.3. Percent fruit infestation (number) caused by fruit flies on cucurbit crops at early, mid and late fruiting stage in kharif season

Varieties	Percent fruit infestation (number) caused by cucurbit fruit flies			
	Early fruiting	Mid fruiting	Late fruiting	Average

	stage		stage		stage			
	Local	Hybrid	Local	Hybrid	Local	Hybrid	Local	Hybrid
Cucumber	18.33 e	20.21 d	36.67 d	38.33 c	46.67 d	47.36 c	33.89 e	35.30 d
Ridge gourd	20.22 d	32.23 a	38.50 c	38.51 c	47.42 c	43.72 e	35.38 d	38.15 b
Snake gourd	14.68 j	14.13 j	33.32 f	38.11 c	34.21 k	36.21 i	27.40 j	28.97 i
Sweet gourd	13.69 k	15.57 i	24.61 i	26.12 gh	32.07 l	35.71 j	23.46 m	25.80 l
Sponge gourd	16.33 gh	16.84 g	33.47 f	34.91 e	40.30 g	42.12 f	30.03 h	31.29 g
Bitter gourd	21.33 c	24.73 b	39.36 b	42.45 a	51.11 b	52.17 a	37.27 c	39.78 a
Bottle gourd	16.46 gh	17.78 f	33.67 f	34.69 e	44.23 e	46.47 d	31.45 g	32.98 ef
Ash gourd	15.51 i	16.06 h	26.36 g	26.40 g	34.69 k	37.58 h	25.52 l	26.68 k
CV (%)	2.67		2.16		1.56		1.46	
LSD $_{(0.05)}$	0.67		0.62		0.78		0.68	

From this above findings it was concluded that, the average percent fruit infestation (number) caused by cucurbit fruit fly was high in hybrid cucurbit crops than local varieties. Again, bitter gourd was found most susceptible crop for cucurbit fruit fly infestation and sweet gourd was more resistant than others.

Rabi season: There was significantly variation among the percent fruit infestation (number) caused by cucurbit fruit fly at different growing stage which was shown in table 4.1.4. In case of early fruiting stage, the average percentfruit infestation (number) caused by cucurbit fruit fly was low in both local and hybrid varietyof sweet gourd (25.16% and 25.89%) followed by ash gourd (25.98% and 27.27%), sponge gourd (29.13% and 29.76%),snake gourd (27.23% and 29.21%), ridge gourd (33.78% and 26.76%), bottle gourd (30.21% and 33.33%) and cucumber (33.69% and 33.38%). On the other hand, thehighest percent of fruit infestation (number)caused by cucurbit fruit fly was observed in both local and hybrid variety of bitter gourd (25.16% and 25.89%). More or less similar trend was observed in mid and late fruiting stage of different cucurbitace crops.

The average percent fruit infestation (number) caused by cucurbit fruit fly was low in both local and hybrid varietyof sweet gourd (44.79% and 46.90%) followed by ash gourd (46.74% and 48.73%), snake gourd (49.40% and 50.62%), sponge gourd (51.12% and 52.20%), bottle gourd

(52.87% and 54.65%), cucumber (54.92% and 56.24%) and ridge gourd (56.69% and 48.34%). On the other hand, the percent fruit infestation (number) caused by cucurbit fruit fly was high in both local and hybrid variety of bitter gourd (59.14% and 60.45%).

Table 4.1.4. Percent fruit infestation (number) caused by fruit flies on cucurbit crops at early, mid and late fruiting stage in rabi season

Varieties	**Percent fruit infestation (number) caused by cucurbit fruit flies**							
	Early fruiting stage		**Mid fruiting stage**		**Late fruiting stage**		**Average**	
	Local	Hybrid	Local	Hybrid	Local	Hybrid	Local	Hybrid
Cucumber	33.69 cd	33.38 d	58.67 e	61.13 cd	72.41 d	74.21 c	54.92 d	56.24 c
Ridge gourd	33.78 c	26.76 h	62.03 c	51.81 i	74.26 c	66.46 h	56.69 c	48.34 i
Snake gourd	27.23 g	29.21 e	51.87 i	52.56 h	69.11 fg	70.29 f	49.40 h	50.62 g
Sweet gourd	25.16 j	25.89 i	49.33 j	51.13 ij	59.89 j	63.68 i	44.79 k	46.90 j
Sponge gourd	25.13 ef	29.76 e	53.13 g	55.39 f	71.12 e	71.46 e	51.12 f	52.20 e
Bitter gourd	38.79 b	39.96 a	63.33 b	65.25 a	75.31 b	76.15 a	59.14 b	60.45 a
Bottle gourd	30.21 d	33.33 d	56.46 f	58.33 e	71.93 de	72.29 d	52.87 e	54.65 d
Ash gourd	25.98 hi	27.27 e	51.12 ij	52.33 h	63.13 i	66.58 h	46.74 j	48.73 hi
CV (%)	3.45		5.67		4.12		3.67	
$LSD_{(0.05)}$	0.78		0.81		0.92		0.68	

From this above findings it was concluded that, the average percent fruit infestation (number) caused by cucurbit fruit flies was high in hybrid cucurbit crops than the local varieties. Again, bitter gourd was found most susceptible crop for cucurbit fruit fly infestation and sweet gourd was more resistant than others.

Comparison of percent fruit infestation (number)caused by fruit fly observed in kharif and rabi season

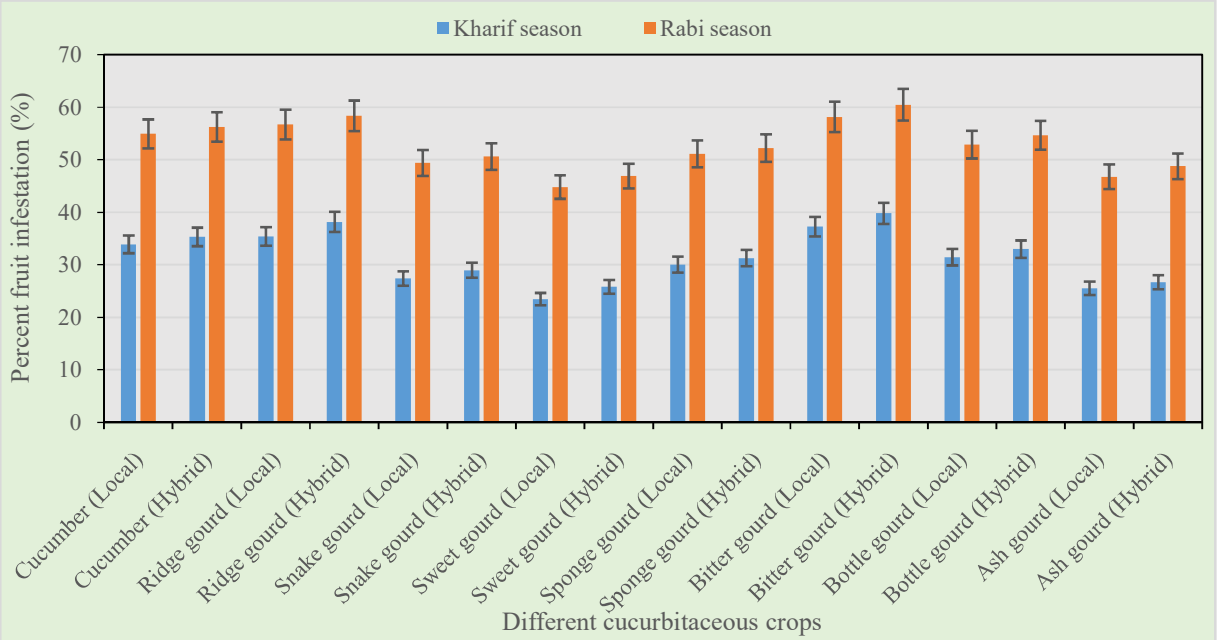

Figure 4.1.2. Comparison between kharif and rabi season in terms of average percent fruit infestation (number) of different cucurbitaceous crops

From this above findings, it was revealed that, the average percent fruit infestation (number) caused by cucurbit fruit fly remain low in kharif season and high in rabi season. Besides this, the highest percent of fruit infestation (number) was found in bitter gourd and the lowest in sweet gourd. More or less researchers also conducted their experiments to identify the host range and fruit infestation rate. Among them Allwood *et al.* 2000 also explore the more or less similar result in case of fruit infestation by cucurbit fruit fly.

4.1.3. Percent fruit infestation (weight) caused by fruit fly

Kharif season: There was significantly variation among the percent fruit infestation (weight) caused by cucurbit fruit fly at different growing stage which was shown in table 4.1.5. In case of early fruiting stage, the average percentfruit infestation (weight) caused by cucurbit fruit fly was

low in both local and hybrid varietyof sweet gourd (32.47% and 33.56%) followed by ash gourd (33.76% and 38.23%), sponge gourd (40.12% and 41.76%),snake gourd (38.84% and 40.33%), ridge gourd (42.52% and 43.63%), bottle gourd (41.67% and 41.33%) and cucumber (41.23% and 42.45%). On the other hand, thehighest percent fruit infestation (weight)caused by cucurbit fruit fly was observed in both local and hybrid variety of bitter gourd (44.71% and 45.13%). More or less similar trend was observed in mid and late fruiting stage of different cucurbitaceous crops.

The average percent fruit infestation (weight) caused by cucurbit fruit fly was low in both local and hybrid varietyof sweet gourd (47.25% and 49.17%) followed by ash gourd (49.68% and 51.41%), snake gourd (51.84% and 53.82%), sponge gourd (53.13% and 54.71%), bottle gourd (54.67% and 56.12%), cucumber (55.91% and 57.47%) and ridge gourd (57.68% and 59.44%). On the other hand, the percent fruit infestation (weight) caused by cucurbit fruit fly was observed high in both local and hybrid variety of bitter gourd (59.96% and 61.47%).

Table 4.1.5. Percent fruit infestation (weight) caused by fruit flies on cucurbit crops at early, mid and late fruiting stage in kharif season

Varieties	Percent fruit infestation (weight) caused by cucurbit fruit flies							
	Early fruiting stage		Mid fruiting stage		Late fruiting stage		Average	
	Local	Hybrid	Local	Hybrid	Local	Hybrid	Local	Hybrid
Cucumber	41.23 f	42.45 d	54.67 de	56.33 c	71.83 g	73.63 e	55.91 ef	57.47 d
Ridge gourd	42.52 d	43.63 c	56.39 c	58.41 b	74.12 d	76.27 c	57.68 c	59.44 b
Snake gourd	38.84 i	40.33 g	51.45 h	53.27 f	65.23 j	67.87 h	51.84 j	53.82 h
Sweet gourd	32.47 l	33.56 k	48.16 j	50.62 i	61.13 m	63.32 l	47.25 l	49.17 k
Sponge gourd	40.12 gh	41.76 e	52.83 g	54.46 e	66.43 i	67.92 h	53.13 i	54.71 g
Bitter gourd	44.71 b	45.13 a	58.06 b	61.11 a	77.12 b	78.17 a	59.96 a	61.47 a
Bottle gourd	41.67 e	41.33 ef	54.52 e	54.73 d	67.82 h	72.29 f	54.67 g	56.12 e
Ash gourd	33.76 k	38.23 j	51.41 h	50.89 i	63.87 k	65.12 j	49.68 k	51.41 j
CV (%)	5.67		6.39		5.88		4.68	
$LSD_{(0.05)}$	0.67		0.56		0.69		0.62	

From this above findings it was concluded that, the average percent fruit infestation (weight) caused by cucurbit fruit fly was high in hybrid cucurbit crops than the local varieties. Again, bitter gourd was found most susceptible crop for cucurbit fruit fly infestation and sweet gourd was more resistant than others.

Rabi season: There was significantly variation among the percent fruit infestation (weight) caused by cucurbit fruit fly at different growing stage which was shown in table 4.1.6. In case of early fruiting stage, the average percentfruit infestation (weight) caused by cucurbit fruit fly was low in both local and hybrid varietyof sweet gourd (45.23% and 51.32%) followed by ash gourd (49.72% and 53.39%), sponge gourd (54.63% and 55.23%),snake gourd (53.19% and 55.04%), ridge gourd (61.67% and 66.93%), bottle gourd (55.98% and 56.67%) and cucumber (60.61% and 66.17%). On the other hand, thehighest percent fruit infestation (weight) caused by cucurbit fruit fly was observed in both local and hybrid variety of bitter gourd (66.07% and 68.89%). More or less similar trend was observed in mid and late fruiting stage of different cucurbit crops. The average percent fruit infestation (weight) caused by cucurbit fruit fly was low in both local and hybrid varietyof sweet gourd (57.75% and 61.16%) followed by ash gourd (59.57% and

64.33%), snake gourd (62.23% and 65.92%), sponge gourd (66.34% and 67.17%), bottle gourd (68.69% and 69.34%), cucumber (71.87% and 75.73%) and ridge gourd (73.13% and 76.46%). On the other hand, the percent fruit infestation (weight) caused by cucurbit fruit fly was high in both local and hybrid variety of bitter gourd (75.54% and 78.87%).

Table 4.1.6. Percent fruit infestation (weight) caused by fruit fly on cucurbit crops at early, mid and last fruiting stage in rabi season

Varieties	**Percent fruit infestation (weight) caused by cucurbit fruit flies**							
	Early fruiting stage		**Mid fruiting stage**		**Late fruiting stage**		**Average**	
	Local	Hybrid	Local	Hybrid	Local	Hybrid	Local	Hybrid
Cucumber	60.61 e	66.17 c	83.16 f	85.33 b	71.83 f	75.69 c	71.87 e	75.73 c
Ridge gourd	61.67 d	66.93 b	84.39 e	85.67 c	73.33 e	76.78 b	73.13 d	76.46 b
Snake gourd	53.19 j	55.04 h	68.27 c	72.39 j	65.23 j	70.33 g	62.23 l	65.92 j
Sweet gourd	45.23 m	51.32 k	59.81 o	67.12 m	68.21 h	65.04 j	57.75 o	61.16 m
Sponge gourd	54.63 i	55.23 h	73.27 i	71.41 k	71.12 f	74.87 d	66.34 i	67.17 h
Bitter gourd	66.07 c	68.89 a	84.92 d	89.56 a	75.63 c	78.17 a	75.54 c	78.87 a
Bottle gourd	55.98 fg	56.67 f	74.87 h	75.23 g	75.21 c	76.13 bc	68.69 g	69.34 f
Ash gourd	49.72 l	53.39 j	63.11 n	71.13 k	65.89 i	68.46 h	59.57 n	64.33 k
CV (%)	6.67		7.34		6.62		4.89	
$LSD_{(0.05)}$	0.78		0.62		0.81		0.66	

From this above findings it was concluded that, the average percent fruit infestation (weight) caused by cucurbit fruit flies was high in hybrid cucurbit crops than the local varieties. Again, bitter gourd was found most susceptible crop for cucurbit fruit fly infestation and sweet gourd was more resistant than others.

Comparison of percent fruit infestation (weight)caused by fruit fly observed in kharif and rabi season

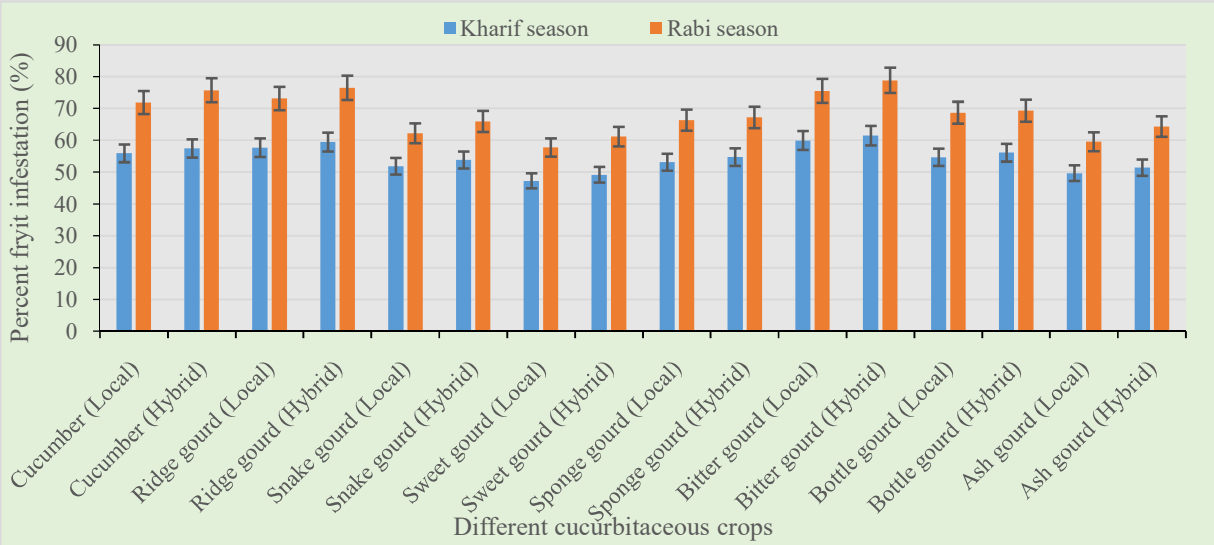

Figure 4.1.3. Comparison between kharif and rabi season in terms of average percent fruit infestation (weight) of different cucurbitaceous crops

From this findings, it was revealed that, the average percent fruit infestation (weight) caused by cucurbit fruit fly remain low in kharif season and high in rabi season. Besides this, the highest percent of fruit infestation (weight) was found in bitter gourd and the lowest in sweet gourd. More or less researchers also conducted their experiments to identify the host range and fruit infestation rate. Among them Allwood *et al.* 2000 also explore the more or less similar result in case of fruit infestation by cucurbit fruit fly.

4.1.4. Percent edible portion of infested fruit

Kharif season: There was significantly variation among the percent edible portion of infested fruit (weight) caused by cucurbit fruit fly at different growing stage which was shown in table 4.1.7. In case of early fruiting stage, the percent edible portion of infested fruit (weight) caused by cucurbit fruit fly was low in both local and hybrid varietyof sweet gourd (31.07% and 38.34%) followed by ash gourd (33.56% and 39.11%), sponge gourd (39.89% and

44.76%),snake gourd (33.16% and 39.59%), ridge gourd (39.49% and 45.78%), bottle gourd (38.04% and 41.23%) and cucumber (39.63% and 43.35%). On the other hand, thehighest percent edible portion of infested fruit (weight) caused by cucurbit fruit fly was observed in both local and hybrid variety of bitter gourd (46.33% and 48.23%). More or less similar trend was observed in mid and late fruiting stage of different cucurbit crops.

The average percent edible portion of infested fruit (weight) caused by cucurbit fruit fly was low in both local and hybrid varietyof sweet gourd (46.92% and 50.45%) followed by ash gourd (47.79% and 53.33%), snake gourd (49.33% and 55.78%), sponge gourd (51.67% and 56.29%), bottle gourd (52.78% and 57.87%), cucumber (54.79% and 59.33%) and ridge gourd (55.25% and 61.19%). On the other hand, the percent edible portion of infested fruit (weight) caused by cucurbit fruit fly was high in both local and hybrid variety of bitter gourd (57.36% and 63.46%).

Table 4.1.7. Percent edible portion of infested fruit (weight) caused by cucurbit fruit fly on cucurbit crops at early, mid and late fruiting stage in kharif season

Varieties	**% edible portion of infested fruit (weight) caused by cucurbit fruit fly**							
	Early fruiting stage		**Mid fruiting stage**		**Late fruiting stage**		**Average**	
	Local	Hybrid	Local	Hybrid	Local	Hybrid	Local	Hybrid
Cucumber	39.63 g	43.35 e	69.96 fg	73.31 c	54.78 f	61.33 b	54.79 h	59.33 c
Ridge gourd	39.49 g	45.78 c	71.13 e	74.33 b	55.13 e	63.46 a	55.25 g	61.19 b
Snake gourd	33.16 j	39.59 g	63.46 k	71.96 d	51.36 de	55.78 d	49.33 m	55.78 g
Sweet gourd	31.07 k	38.34 i	61.23 l	64.67 j	48.46 k	48.33 k	46.92 o	50.45 l
Sponge gourd	39.89 g	44.76 d	65.83 i	69.78 g	49.29 j	54.33 f	51.67 k	56.29 f
Bitter gourd	46.33 b	48.23 a	70.63 f	80.78 a	55.11 e	61.36 b	57.36 e	63.46 a
Bottle gourd	38.04 i	41.23 f	68.54 h	71.56 d	51.76 h	60.82 c	52.78 j	57.87 d
Ash gourd	33.56 j	39.11 h	59.89 m	68.54 h	49.92 hi	52.33 g	47.79 n	53.33 i
CV (%)	1.46		1.62		1.53		1.48	
LSD $_{(0.05)}$	0.78		0.88		0.79		0.62	

From this above findings it was concluded that, the percent edible portion of infested fruit (weight) caused by cucurbit fruit fly was high in hybrid cucurbit crops than the local varieties. Again, bitter gourd was found more susceptible crop for cucurbit fruit fly infestation and sweet gourd was more resistant than others.

Rabi season: There was significantly variation among the percent edible portion of infested fruit (weight) caused by cucurbit fruit fly at different growing stage which was shown in table 4.1.8. In case of early fruiting stage, the percent edible portion of infested fruit (weight) caused by cucurbit fruit fly was low in both local and hybrid varietyof sweet gourd (49.13% and 49.22%) followed by ash gourd (54.23% and 54.47%), sponge gourd (62.13% and 67.32%),snake gourd (56.23% and 62.94%), ridge gourd (66.89% and 72.78%), bottle gourd (63.33% and 68.11%) and cucumber (66.36% and 70.76%). On the other hand, thehighest percent edible portion of infested fruit (weight) caused by cucurbit fruit fly was observed in both local and hybrid variety of bitter gourd (71.12% and 73.78%). More or less similar trend was observed in mid and late fruiting stage of different cucurbit crops.

The average percent edible portion of infested fruit (weight) caused by cucurbit fruit fly was low in both local and hybrid varietyof sweet gourd (61.13% and 61.19%) followed by ash gourd (65.35% and 66.87%), snake gourd (56.23% and 62.94%), sponge gourd (62.13% and 67.32%), bottle gourd (63.33% and 68.11%), cucumber (66.36% and 70.76%) and ridge gourd (66.89% and 72.78%). On the other hand, the percent edible portion of infested fruit (weight) caused by cucurbit fruit fly was high in both local and hybrid variety of bitter gourd (71.12% and 73.78%).

Table 4.1.8. Percent edible portion of infested fruit (weight) caused by cucurbit fruit fly on cucurbit crops at early, mid and late fruiting stage in rabi season

Varieties	% edible portion of infested fruit (weight) caused by cucurbit fruit fly							
	Early fruiting stage		Mid fruiting stage		Late fruiting stage		Average	
	Local	Hybrid	Local	Hybrid	Local	Hybrid	Local	Hybrid
Cucumber	66.36 gh	70.76 d	83.23 e	84.96 c	74.42 g	79.96 d	74.67 g	78.56 c
Ridge gourd	66.89 g	72.78 b	83.78 d	86.33 b	75.33 f	81.06 b	75.33 f	80.06 b
Snake gourd	56.23 k	62.94 i	79.41 h	81.53 g	66.78 j	72.45 h	67.47 k	72.31 i
Sweet gourd	49.13 m	49.22 m	74.56 k	74.58 k	59.69 m	59.77 m	61.13 n	61.19 n
Sponge gourd	62.13 j	67.32 f	81.93 f	83.59 d	69.11 i	75.67 f	71.06 j	75.53 e
Bitter gourd	71.12 c	73.78 a	84.92 c	87.45 a	80.33 c	82.13 a	78.79 c	81.12 a
Bottle gourd	63.33 i	68.11 e	81.89 f	84.98 c	73.72 g	76.92 e	72.98 h	76.67 d
Ash gourd	54.23 l	54.47 l	76.71 j	77.23 i	65.12 l	65.91 k	65.35 m	66.87 l
CV (%)	1.22		1.67		1.31		1.23	
LSD $_{(0.05)}$	0.87		0.93		0.88		0.78	

From this above findings it was concluded that, the percent edible portion of infested fruit (weight) caused by cucurbit fruit fly was high in hybrid cucurbit crops than the local varieties. Again, bitter gourd was found most susceptible crop for cucurbit fruit fly infestation and sweet gourd was more resistant than others.

Comparison of percent edible portion of infested fruit (weight)caused by fruit fly observed in kharif and rabi season

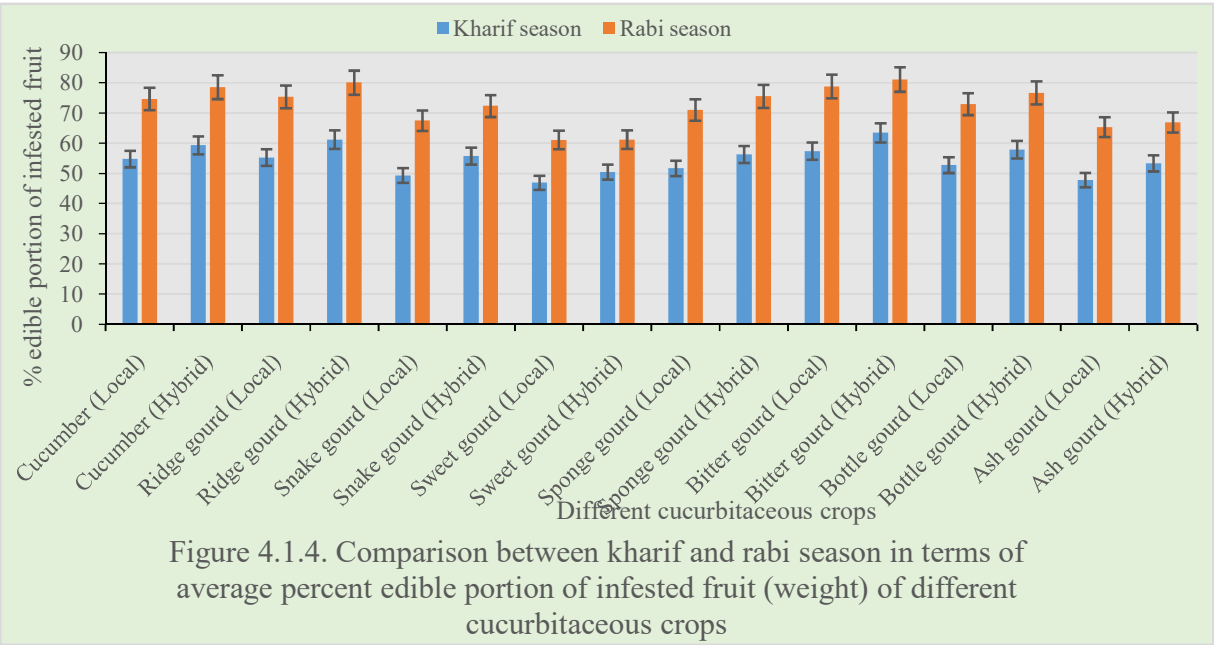

Figure 4.1.4. Comparison between kharif and rabi season in terms of average percent edible portion of infested fruit (weight) of different cucurbitaceous crops

From this above findings, it was revealed that, the average percent edible portion of infested fruit (weight) caused by cucurbit fruit fly remain low in kharif season and high in rabi season. Besides this, highest percent edible portion of infested fruit (weight) caused by cucurbit fruit fly was found in bitter gourd and low in sweet gourd. More or less researchers also conducted their experiments to identify the host range and fruit infestation rate. Among them Allwood *et al.* 2000 also explore the more or less similar result in case of fruit infestation by cucurbit fruit fly.

4.1.5. Number of bore on infested fruits

Kharif season: There was significantly variation among the number of bore on infested fruit caused by cucurbit fruit fly at different growing stage which was shown in table 4.1.9. In case of early fruiting stage, the number of bore on infested fruit caused by cucurbit fruit fly was low in both local and hybrid varietyof sweet gourd (2.12 and 2.36 bores) followed by ash gourd (2.38 and 2.36 bores), sponge gourd (2.49 and 2.59 bores),snake gourd (2.31 and 2.52 bores), ridge gourd (2.83 and 3.07 bores), bottle gourd (2.63 and 2.72 bores) and cucumber (2.78 and 2.81 bores). On the other hand, thehighest number of bore on infested fruit caused by cucurbit fruit fly was observed in both local and hybrid variety of bitter gourd (3.03 and 3.98 bores). More or less similar trend was observed in mid and late fruiting stage of different cucurbit crops.

The average number of bore on infested fruit caused by cucurbit fruit fly was low in both local and hybrid varietyof sweet gourd (2.56 and 2.92 bores) followed by ash gourd (2.98 and 3.23 bores), snake gourd (3.19 and 3.47 bores), sponge gourd (3.41 and 3.63 bores), bottle gourd (3.62 and 3.71 bores), cucumber (3.87 and 3.91 bores) and ridge gourd (4.03 and 4.29 bores). On the other hand, the average number of bore on infested fruit caused by cucurbit fruit fly was high in both local and hybrid variety of bitter gourd (4.26 and 4.89 bores).

Table 4.1.9: Number of bore on infested fruits by cucurbit fruit fly on cucurbit crops at early, mid and late fruiting stage in kharif season

Varieties	Number of bore on infested fruits caused by cucurbit fruit fly							
	Early fruiting stage		Mid fruiting stage		Late fruiting stage		Average	
	Local	Hybrid	Local	Hybrid	Local	Hybrid	Local	Hybrid
Cucumber	2.78 c	2.81 c	4.56 de	4.61 d	4.27 cd	4.31 c	3.87 c	3.91 c
Ridge gourd	2.83 c	3.07 b	4.92 c	5.32 c	4.33 c	4.47 b	4.03 c	4.29 b
Snake gourd	2.31 h	2.52 f	4.13 f	4.33 ef	3.12 f	3.56 e	3.19 f	3.47 e
Sweet gourd	2.12 i	2.36 h	3.16 h	3.51 g	2.41 h	2.89 g	2.56 h	2.92 fg
Sponge gourd	2.49 g	2.59 g	4.46 e	4.67 d	3.29 f	3.63 e	3.41 e	3.63 d
Bitter gourd	3.03 b	3.98 a	5.29 b	5.79 a	4.47 b	4.89 a	4.26 b	4.89 a
Bottle gourd	2.63 e	2.72 d	4.62 d	4.34 ef	3.61 e	4.07 d	3.62 d	3.71 cd
Ash gourd	2.38 h	2.36 h	3.62 g	4.18 f	2.93 fg	3.16 f	2.98 f	3.23 ef
CV (%)	0.89		0.78		0.92		0.81	
$LSD_{(0.05)}$	0.32		0.46		0.36		0.42	

From this above findings it was concluded that, the average number of bore on infested fruits caused by cucurbit fruit fly was high in hybrid cucurbit crops than the local varieties. Again, bitter gourd was found more susceptible crop for cucurbit fruit fly infestation and sweet gourd was more resistant than others.

Rabi season: There was significantly variation among the number of bore on infested fruit caused by cucurbit fruit fly at different growing stage which was shown in table 4.1.10. In case of early fruiting stage, the number of bore on infested fruit caused by cucurbit fruit fly was low in both local and hybrid varietyof sweet gourd (2.48 and 2.73 bores) followed by ash gourd (2.63 and 2.61 bores), sponge gourd (3.05 and 3.91 bores),snake gourd (2.56 and 3.06 bores), ridge gourd (3.91 and 4.78 bores), bottle gourd (3.56 and 3.89 bores) and cucumber (3.87 and 4.11 bores). On the other hand, thehighest number of bore on infested fruit caused by cucurbit fruit fly was observed in both local and hybrid variety of bitter gourd (4.34 and 4.89 bores). More or less similar trend was observed in mid and late fruiting stage of different cucurbit crops.

The average number of bore on infested fruit caused by cucurbit fruit fly was low in both local and hybrid varietyof sweet gourd (3.17 and 3.43 bores) followed by ash gourd (3.33 and 3.86 bores), sponge gourd (4.11 and 4.69 bores),snake gourd (3.76 and 4.13 bores), ridge gourd (4.72 and 5.61 bores), bottle gourd (4.46 and 4.87 bores) and cucumber (4.67 and 5.03 bores). On the other hand, the average number of bore on infested fruit caused by cucurbit fruit fly was high in both local and hybrid variety of bitter gourd (5.34 and 5.89 bores).

Table 4.1.10. Number of bore on infested fruits caused by cucurbit fruit fly at early, mid and late fruiting stage in rabi season

Varieties	**Number of bore on infested fruits caused by cucurbit fruit fly**							
	Early fruiting stage		**Mid fruiting stage**		**Late fruiting stage**		**Average**	
	Local	Hybrid	Local	Hybrid	Local	Hybrid	Local	Hybrid
Cucumber	3.87 c	4.11 b	5.92 c	6.32 b	4.23 d	4.66 c	4.67 d	5.03 c
Ridge gourd	3.91 c	4.78 a	5.96 c	6.52 b	4.31 d	5.53 a	4.72 d	5.61 a
Snake gourd	2.56 fg	3.06 e	5.33 e	5.23 e	3.38 ef	4.11 d	3.76 f	4.13 e
Sweet gourd	2.48 g	2.73 f	3.78 g	4.12 f	3.25 f	3.45 e	3.17 h	3.43 g
Sponge gourd	3.05 e	3.91 c	5.21 e	5.89 d	4.06 d	4.27 d	4.11 e	4.69 d
Bitter gourd	4.34 b	4.89 a	6.41 b	7.12 a	5.26 b	5.67 a	5.34 b	5.89 a
Bottle gourd	3.56 d	3.89 cd	5.71 d	6.15 c	4.12 d	4.56 c	4.46 e	4.87 d
Ash gourd	2.63 f	2.61 f	4.12 f	5.52 d	3.23 f	3.46 e	3.33 g	3.86 f
CV (%)	0.36		0.48		0.58		0.42	
$LSD_{(0.05)}$	0.52		0.46		0.46		0.64	

From this findings it was concluded that, the average number of cucurbit fruit fly incidence was high in hybrid cucurbit crops than the local varieties. Again, bitter gourd was found most susceptible crop for cucurbit fruit fly infestation and sweet gourd was more resistant than others.

Comparison of number of bores on infested fruitcaused by fruit fly observed in kharif and rabi season

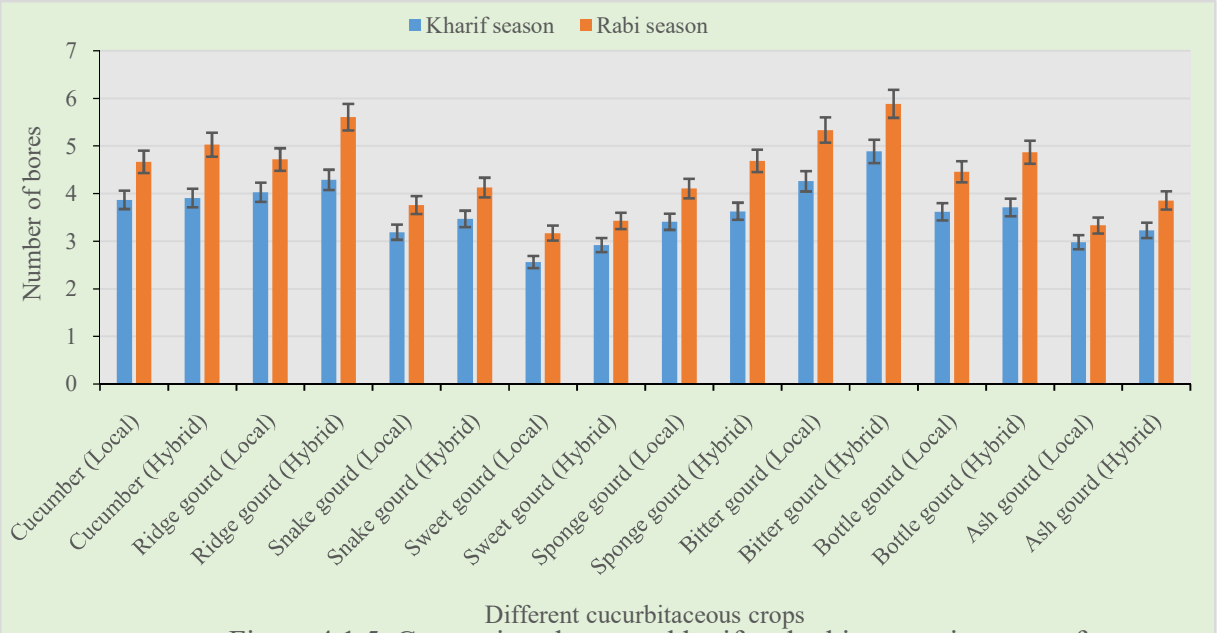

Figure 4.1.5. Comparison between kharif and rabi season in terms of average number of bores on infested fruits of different cucurbitaceous crops

From this above findings, it was revealed that, the average number of bore on infested fruit caused by cucurbit fruit fly remain low in kharif season and high in rabi season. Besides this, the highest number of bore on infested fruit caused by cucurbit fruit fly was found in bitter gourd and the lowest in sweet gourd. More or less researchers also conducted their experiments to identify the host range and fruit infestation rate. Among them Allwood *et al.* 2000 also explore the more or less similar result in case of fruit infestation by cucurbit fruit fly.

Experiment 2: Study on the bio-ecology of cucurbit fruit fly while infesting cucurbitaceous vegetables

The results of the present study regarding the bio-ecological development of cucurbit fruit fly as well as the effect of weather factors on the performance of incubation, larval period, pupal period, adult longevity and reproductive dynamics conducted in the laboratory of the Department of Entomology at SAU, Dhaka during July 2017 to September 2017 have been discussed and presented with interpretations under the following sub-headings:

4.2.1. Growth and development of cucurbit fruit fly

Variations among the growth and developmental periods of cucurbit fruit flywere observed in this study.

4.2.1.1. Egg

During the present study, it was observed that, cucurbit fruit flies laid their eggs in the fresh cucurbit fruit flashes in the field condition. In laboratory condition, the eggs were laid on the blotting paper (Whatman filter paper no.1) of petridishes. The eggs were usually laid singly or in clusters. The freshly laid eggs of cucurbit fruit flies were creamy white, oblong, banana shaped, posterior portion was broadly rounded and anterior portion was more pointed. The eggs were attached to the surface vertically or slightly at an angle and touching each other. Incubation period of cucurbit fruit flies eggs ranged from 1 to 3 days at room temperature (±30℃ and ± 85 RH) and from 2 to 4 days at laboratory condition (25^{o}C and 80% RH). Average incubation period of room temperature and laboratory condition were 1.7 ± 0.823 days and 2.7 ± 0.823 days, respectively (Table 4.2.1). These observations were strongly supported by Gupta and Verma, 1995, Koul and Bhagat, 1994; Hollingsworth *et al.* 1997 and Sohrab, *et al.* 2018.

The length and breadth of eggs of cucurbit fruit flies were from 1.09 to 1.30 mm and 0.21 to 0.24 mm, respectively. Average length and breadth of cucurbit fruit flies eggs were 1.14 ± 0.07 mm and 0.22 ± 0.01 mm, respectively (Table 4.2.1). These observations were strongly supported by Mir *et al.* (2014), Lanjar *et al.* (2013), Shivayya *et al.* (2007) and Dhillon *et al.* (2005). They founded more or less same results of length (average 1.13 ± 0.14 mm) and breadth (average o.28 ± 0.05 mm) of eggs of cucurbit fruit fly.

Table 4.2.1. Incubation period of cucurbit fruit fly and length and breadth of eggs

Incubation period	**Minimum (Days)**	**Maximum (Days)**	**Average ± SD (Days)**
Room Temperature (±30°C and ± 85 RH)	1	3	1.7 ± 0.823
Laboratory Condition (25°C and 80% RH)	2	4	2.7 ± 0.823
Measurement of egg			
	Minimum (mm)	**Maximum (mm)**	**Average ± SD (mm)**
Length	1.09	1.30	1.14 ± 0.07
Breadth	0.21	0.24	0.22 ± 0.01

4.2.1.3. Larval period

The maggot come out by making irregular hole through the upper egg shell and inter into the tender fruits and start feeding. The full grown maggot were barrel shaped and light brown in color. Larval or maggot period of cucurbit fruit flies ranged from 3 to 5 days at room temperature (±30°C and ± 85 RH) and from 4 to 7 days at laboratory condition (25°C and 80% RH). Average larval period of room temperature and laboratory condition were 4.3 ± 0.675 days and 5.5± 0.85 days respectively (Table 3). These observations were strongly supported by Manzar and Srivastava (2007), Shivay *et al.* (2007), Ullah *et al.* (2008) and Lanjar *et al.* (2013).

The length and breadth of full grown maggot of cucurbit fruit flies ranged from 7.7 to 10.3 mm and 1.96 to 2.13 mm respectively. Average length and breadth of cucurbit fruit flies larvae were 7.9 ± 0.994 mm and 2.04 ± 0.062 mm respectively (Table 4.2.2). These observations were

strongly supported by Mir *et al.* (2014), Lanjar *et al.* (2013), Shivayya *et al.* (2007) and Dhillon *et al.* (2005). They founded more or less same results of length (average 9.62 ± 0.87 mm) and breadth (average 2.05 ± 0.32 mm) of larvae of cucurbit fruit fly.

Table 4.2.2. Larval period of cucurbit fruit fly and measurement of larvae

Larval period	**Minimum (Days)**	**Maximum (Days)**	**Average ± SD (Days)**
Room Temperature (±30°C and ± 85 RH)	3	5	4.3 ± 0.675
Laboratory Condition (25°C and 80% RH)	4	7	5.5 ± 0.85
Measurement of larvae			
	Minimum (mm)	**Maximum (mm)**	**Average ± SD (mm)**
Length	7.7	10.3	7.9 ± 0.994
Breadth	1.96	2.13	2.04 ± 0.062

4.2.1.3. Pupal period

The full grown maggot go into the soil and get pupation. Pupal period depends on the structure and texture of the soil. The pupa is cylindrical in shape and reddish yellow to pale white in color. Pupal period of cucurbit fruit flies ranged from 5 to 7 days at room temperature (±30°C and ± 85 RH) and from 9 to 12 days at laboratory condition (25°C and 80% RH). Average pupal period of room temperature and laboratory condition were 5.9 ± 0.738 days and 9.8 ± 1.033 days respectively (Table 4.2.3). These observations were more or less similar with the observations of the researchers likeLanjar *et al.* (2013),Rituraj(2011), Ullah *et al.* (2008) and Shivayya *et al.* (2007).

The length and breadth of pupa of cucurbit fruit flies ranged from 5.8 to 8.2 mm and 2.22 to 2.72 mm respectively. Average length and breadth of cucurbit fruit flies pupa were 6.2 ± 1.135 mm and 2.38 ± 0.161 mm respectively (Table 4.2.3). These observations were strongly supported by many researchers. Rituraj (2011) observed the pupa of cucurbit fruit fly and found 4-5 mm length and 2 mm breadth (Lanjar *et al.,* 2013;Shivayya *et al.,* 2007and Dhillon *et al.,* 2005).

Table 4.2.3. Pupal period of cucurbit fruit fly and measurement of pupa

Incubation period	**Minimum (Days)**	**Maximum (Days)**	**Average ± SD (Days)**
Room Temperature (±30°C and ± 85 RH)	5	7	5.9 ± 0.738
Laboratory Condition (25°C and 80% RH)	9	12	9.8 ± 1.033
Measurement of pupa			
	Minimum (mm)	**Maximum (mm)**	**Average ± SD (mm)**
Length	5.8	8.2	6.2 ± 1.135
Breadth	2.22	2.72	2.38 ± 0.161

4.2.1.4. Adult longevity

The adult fruit flies are reddish brown in color with yellow stripes on its dorsal thorax and has brown spots along the veins otherwise clear wings. Adult longevity of male cucurbit fruit flies under room temperature and laboratory condition were ranged from 5 to 7 days and 12 to 15 days respectively. Average adult longevity of male cucurbit fruit flies under room temperature and laboratory condition were 5.9 ± 0.568 days and 13.3 ± 0.95 days respectively (Table 4.2.4). Adult longevity of female cucurbit fruit flies under room temperature and laboratory condition were ranged from 6 to 8 days and 14 to 18 days respectively. Average adult longevity of female cucurbit fruit flies under room temperature and laboratory condition were 6.7 ± 0.675 days and 15.8 ± 1.229 days respectively (Table 4.2.4). These observations were more or less similar with many researchers likeMir *et al.* (2014), Lanjar *et al.* (2013), Ullah *et al.* (2008), Shivay *et al.* (2007) andSrivastava (2007).

The length and breadth of adult male of cucurbit fruit flies were ranged from 6.2 to 9.8 mm and 10.98 to 12.28 mm respectively. Average length and breadth of adult male cucurbit fruit flies were 7.4 ± 1.075 mm and 11.4 ± 0.342 mm respectively (Table 4.2.4). The length and breadth of adult female of cucurbit fruit flies were ranged from 8.8 to 11.1 mm and 15.12 to 16.67 mm respectively. Average length and breadth of adult female cucurbit fruit flies were 9.3 ± 0.823 mm and 15.69 ± 0.418 mm respectively (Table 4.2.4). These observations more or less similar with

other researchers. Lanjar *et al.* (2013) observed the length (8.74 ± 0.32 mm) and breadth (11.46 ± 1.16 mm) of male cucurbit fruit fly and the length (9.94 ± 0.20 mm) and breadth (15.92 ± 0.74 mm) of female cucurbit fruit fly(Mitchell *et al.,*1965 and Feron *et al.,* 1958).

Table 4.2.4. Adult longevity of cucurbit fruit fly and measurement of adults

Adult longevity	**Minimum (Days)**	**Maximum (Days)**	**Average ± SD (Days)**
Male			
Room Temperature (±30℃ and ± 85 RH)	5	7	5.9 ± 0.568
Laboratory Condition (25℃ and 80% RH)	12	15	13.3 ± 0.95
Female			
Room Temperature (±30℃ and ± 85 RH)	6	8	6.7 ± 0.675
Laboratory Condition (25℃ and 80% RH)	14	18	15.8 ± 1.229
Measurement of adults			
	Minimum (mm)	**Maximum (mm)**	**Average ± SD (mm)**
Male			
Length	6.2	9.8	7.4 ± 1.075
Breadth	10.98	12.28	11.4 ± 0.342
Female			
Length	8.8	11.1	9.3 ± 0.823
Breadth	15.12	16.67	15.69 ± 0.418

4.2.1.5. Total life span

Total life cycle means the day duration from the first day of egg hatched to death of an adult. Total life cycle of cucurbit fruit flies for adult male under room temperature and laboratory condition were 16.1 ± 1.1 days and 28.6 ± 2.171 days respectively. Total life cycle of cucurbit fruit flies for adult female under room temperature and laboratory condition were 16.9 ± 1.287 days and 31.1± 2.514 days respectively. Average ovipositional period of adult female cucurbit fruit flies under room temperature and laboratory condition were 1.4 ± 0.516 days and 2.9 ± 0.738 days respectively (Table 4.2.5).

Table 4.2.5. Total life cycle of cucurbit fruit fly at room temperature and laboratory condition

Life cycle	**Room Temperature (±30°C and ± 85 RH)**	**Laboratory Condition (25°C and 80% RH)**
Incubation period (days)	1.7 ± 0.823	2.7 ± 0.823
Larval period (days)	4.3 ± 0.675	5.5 ± 0.85
Pupal period (days)	5.9 ± 0.738	9.8 ± 1.033
Male adult longevity (days)	5.9 ± 0.568	13.3 ± 0.95
Female adult longevity (days)	6.7 ± 0.675	15.8 ± 1.229
Total life cycle for male (days)	16.1 ± 1.1	28.6 ± 2.171
Total life cycle for female (days)	16.9 ± 1.287	31.1 ± 2.514
Oviposition period (days)	1.4 ± 0.516	2.9 ± 0.738

Experiment 3: Evaluation of the efficacy of management practices along with bio-pesticides against cucurbit fruit fly

This chapter comprises the evaluation of the efficacy of management practices along with bio-pesticides against cucurbit fruit fly. The data have been presented and discussed and possible interpretations are made under the following sub-headings:

4.3.1. Fruit infestation(number)

4.3.1.1. Early fruiting stage

The effect of management practices on fruit infestation (number) at early fruiting stage has been shown in Table 4.3.1. Significant variations were observed among the treatments in terms of cucurbit fruit fly infestation on bitter gourd. The highest number of fruit plot^{-1} (11.33 fruits/plot) was recorded in treatment T_2, which was statistically different from others, followed by T_1 (8.33 fruits/plot), T_3 (8.00 fruits/plot) and T_7 (7.00 fruits/plot). On the other hand, the lowest number of fruit plot^{-1} (4.33 fruits/plot) was recorded in treatment T_8, which was statistically similar with T_4 (4.67 fruits/plot), followed by T_6 (6.00 fruits/plot) and T_5 (6.67 fruits/plot).

The lowest number of infested fruit plot^{-1} (2.00 fruits/plot) was recorded in treatment T_2, which is statistically similar with T_1 (2.00 fruits/plot) and T_3 (2.67 fruits/plot). And the highest number of infested fruit plot^{-1} (3.67 fruits/plot) was recorded in treatment T_7, which was statistically similar with T_8(3.33 fruits/plot), T_6(3.33 fruits/plot), T_4(3.33 fruits/plot) and T_5 (3.00 fruits/plot) (Table 4.3.1).

Considering the level of infestation, the lowest fruit infestation (17.85%) (number) was recorded in treatment T_2, which was statistically similar with T_1 (24.07%), followed by T_3 (33.13%) and T_5 (45.24%). On the other hand, the highest fruit infestation (number) was recorded in treatment

T_8(76.67%), which was statistically similar with T_4 (71.67%), followed by T_6 (55.56%) and T_7 (52.38%) (Table 4.3.1).

Considering the reduction of fruit infestation, the highest reduction of fruit infestation (number) over control was observed 76.72% in treatment T_2, followed by T_1 (68.61%), T_3 (56.79%) and T_5 (40.99%). Whereas the lowest reduction of fruit infestation (number) over control was observed in T_4 (6.52%), followed by T_6 (27.53%) and T_7 (31.68%) (Table 4.3.1).

Table 4.3.1. Effect of management practices on fruit infestation (number) at early fruiting stage

Treatment	% fruit infestation(number) at early fruiting stage			
	Total no. of fruit plot^{-1}	No. of infested fruit plot^{-1}	% fruit infestation	% reduction of fruit infestation over control
T_1	8.33 b	2.00 c	24.07 de	68.61
T_2	11.33 a	2.00 c	17.85 e	76.72
T_3	8.00 bc	2.67 bc	33.13 cd	56.79
T_4	4.67 e	3.33 ab	71.67 a	6.52
T_5	6.67 d	3.00 ab	45.24 bc	40.99
T_6	6.00 d	3.33 ab	55.56 b	27.53
T_7	7.00 cd	3.67 a	52.38 b	31.68
T_8	4.33 e	3.33 ab	76.67 a	0.00
CV(%)	10.57	15.20	15.41	-
$LSD_{(0.05)}$	1.26	0.75	12.25	-

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT). Here, T_1= Setting up of pheromone trap replaced at 1 month interval, T_2= Setting up of poison bait trap @ 2 gm Sevin 85 WP mixed with 100 g mashed sweet gourd and 10 ml molasses replaced at 4 days interval, T_3= Bait spray @ 10 ml molasses and 1 ml Malathion mixed with 1 liter of water @ 7 days interval, T_4= Spraying of spinosad @ 0.08 ml per liter of water at 7 days interval, T_5= Spraying of neem oil @ 3 ml neem oil and 10 ml Trix mixed with 1 liter of water @ 7 days interval,T_6= Spraying of neem seed kernel extract @ 3 ml neem seed kernel extract and 10 ml Trix mixed with 1 liter of water @ 7 days interval, T_7= Spraying of Malathion 57 EC @ 1 ml mixed with 1 liter of water @ 7 days interval, T_8= Untreated control]

From the above findings it was revealed that the lowest fruit infestation (6.28%) (number) was recorded in treatment T_2 using the poison bait trap in the field, where the highest reduction of fruit infestation over control was 76.72%. As a result, the order of efficacy of management practices in terms of fruit infestation reduction(number) is $T_2>T_1>T_3>T_5>T_7>T_6>T_4>T_8$.

4.3.1.2. Mid fruiting stage

The effect of management practices on fruit infestation (number) at mid fruiting stage has been shown in Table 4.3.2. Significant variations were observed among the treatments in terms of cucurbit fruit fly infestation on bitter gourd. The highest number of fruit plot^{-1} (28.33 fruits/plot) was recorded in treatment T_2, which was statistically different from others, followed by T_1 (23.00 fruits/plot), T_3 (22.67 fruits/plot) and T_7 (21.67 fruits/plot). On the other hand, the lowest number of fruit plot^{-1} (14.67 fruits/plot) was recorded in treatment T_8, which was statistically different from others, followed by T_4 (17.67 fruits/plot), T_6 (19.67 fruits/plot) and T_5 (20.67 fruits/plot).

The lowest number of infested fruit plot^{-1} (3.67 fruits/plot) was recorded in treatment T_2, which is statistically similar with T_1 (4.33 fruits/plot) and T_3 (5.00 fruits/plot). And the highest number of infested fruit plot^{-1} (11.67 fruits/plot) was recorded in treatment T_8, which was statistically similar with T_4(9.33 fruits/plot), T_6(8.00 fruits/plot), T_5(7.67 fruits/plot) and T_7(7.00 fruits/plot) (Table 4.3.2).

Considering the level of infestation, the lowest fruit infestation (12.89%) (number) was recorded in treatment T_2, which was statistically similar with T_1 (18.74%), followed by T_3 (22.00%) and T_7 (32.25%). On the other hand, the highest fruit infestation(number) was recorded in treatment T_8 (79.46%), which was statistically different from others, followed by T_4 (52.72%), T_6 (40.61%) and T_5 (37.06%) (Table 4.3.2).

Considering the reduction of fruit infestation, the highest reduction of fruit infestation (number) over control was observed (83.78%) in treatment T_2, followed by T_1 (76.42%), T_3 (72.31%) and T_7 (59.41%). Whereas the lowest reduction of fruit infestation (number) over control was observed in T_4 (33.65%), followed by T_6 (48.89%) and T_5 (53.36%) (Table 4.3.2).

Table 4.3.2. Effect of management practices on fruit infestation (number) at mid fruiting stage

Treatment	% fruit infestation(number) at mid fruiting stage			
	Total no. of fruit plot^{-1}	No. of infested fruit plot^{-1}	% fruit infestation	% reduction of fruit infestation over control
T_1	23.00 b	4.33 d	18.74 ef	76.42
T_2	28.33 a	3.67 d	12.89 f	83.78
T_3	22.67 b	5.00 d	22.00 e	72.31
T_4	17.67 e	9.33 b	52.72 b	33.65
T_5	20.67 cd	7.67 c	37.06 cd	53.36
T_6	19.67 d	8.00 bc	40.61 c	48.89
T_7	21.67 bc	7.00 c	32.25 d	59.41
T_8	14.67 f	11.67 a	79.46 a	0.00
CV(%)	4.32	11.32	12.74	-
$LSD_{(0.05)}$	1.54	1.35	7.95	-

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT). Here, T_1= Setting up of pheromone trap replaced at 1 month interval, T_2= Setting up of poison bait trap @ 2 gm Sevin 85 WP mixed with 100 g mashed sweet gourd and 10 ml molasses replaced at 4 days interval, T_3= Bait spray @ 10 ml molasses and 1 ml Malathion mixed with 1 liter of water @ 7 days interval, T_4= Spraying of spinosad @ 0.08 ml per liter of water at 7 days interval, T_5= Spraying of neem oil @ 3 ml neem oil and 10 ml Trix mixed with 1 liter of water @ 7 days interval,T_6= Spraying of neem seed kernel extract @ 3 ml neem seed kernel extract and 10 ml Trix mixed with 1 liter of water @ 7 days interval, T_7= Spraying of Malathion 57 EC @ 1 ml mixed with 1 liter of water @ 7 days interval, T_8= Untreated control]

From the above findings it was revealed that, the lowest fruit infestation (12.89%) (number) was recorded in treatment T_2 using the poison bait trap in the field, where the highest reduction of fruit infestation (number) over control was 83.78%. As a result, the order of efficacy of management practices in terms of fruit infestation reduction (number) is $T_2>T_1>T_3>T_7>T_5>T_6>T_4>T_8$.

4.3.1.3. Late fruiting stage

Effect of management practices on fruit infestation (number) at late fruiting stage has been shown in Table 4.3.3. Significant variations were observed among the treatments in terms of fruit fly infestation on bitter gourd. The highest number of fruit plot^{-1} (22.67 fruits/plot) was recorded in treatment T_2, which is statistically different from others, followed by T_1 (18.67 fruits/plot), T_3 (17.33 fruits/plot) and T_7 (16.00 fruits/plot). On the other hand, the lowest number of fruits plot^{-1} (13.00 fruits/plot) was recorded in treatment T_8.

The lowest number of infested fruit plot^{-1} (3.33 fruits/plot) was recorded in treatment T_2, which is statistically similar with T_1 (3.67 fruits/plot), followed by T_3 (4.33 fruits/plot). And the highest number of infested fruit plot^{-1} (11.33 fruits/plot) was recorded in treatment T_8, which was statistically different from others, followed by T_4(9.33 fruits/plot), T_6(8.00 fruits/plot), T_5(7.67 fruits/plot) and T_7(7.00 fruits/plot) (Table 4.3.3).

Considering the level of infestation, the lowest fruit infestation (14.67%) (number) was recorded in treatment T_2, which is statistically similar with T_1 (19.69%), followed by T_3 (25.28%) and T_7 (33.41%). On the other hand, the highest fruit infestation (number) was recorded in T_9 (87.33%) (Table 4.3.3).

Considering the reduction of fruit infestation (number), the highest reduction of fruit infestation over control was observed (83.20%) in treatment T_2, followed by T_1 (77.45%), T_3 (71.05%) and T_7 (61.74%). Whereas the lowest reduction of fruit infestation (number) over control was observed in T_4 (30.16%), T_6 (43.82%) and T_5 (50.81%) (Table 4.3.3).

Table 4.3.3. Effect of management practices on fruit infestation (number) at late fruiting stage

Treatment	% fruit infestation (number) at late fruiting stage			
	Total no. of fruit plot^{-1}	No. of infested fruit plot^{-1}	% fruit infestation	% reduction of fruit infestation over control
T_1	18.67 b	3.67 ef	19.69 ef	77.45
T_2	22.67 a	3.33 f	14.67 f	83.20
T_3	17.33 bc	4.33 e	25.28 de	71.05
T_4	13.67 e	8.33 b	60.99 b	30.16
T_5	15.00 de	6.33 c	42.96 c	50.81
T_6	14.33 de	7.00 c	49.06 c	43.82
T_7	16.00 cd	5.33 d	33.41 d	61.74
T_8	13.00 e	11.33 a	87.33 a	0.00
CV(%)	7.18	6.92	11.75	-
$LSD_{(0.05)}$	1.98	0.73	8.27	-

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT). Here, T_1= Setting up of pheromone trap replaced at 1 month interval, T_2= Setting up of poison bait trap @ 2 gm Sevin 85 WP mixed with 100 g mashed sweet gourd and 10 ml molasses replaced at 4 days interval, T_3= Bait spray @ 10 ml molasses and 1 ml Malathion mixed with 1 liter of water @ 7 days interval, T_4= Spraying of spinosad @ 0.08 ml per liter of water at 7 days interval, T_5= Spraying of neem oil @ 3 ml neem oil and 10 ml Trix mixed with 1 liter of water @ 7 days interval,T_6= Spraying of neem seed kernel

extract @ 3 ml neem seed kernel extract and 10 ml Trix mixed with 1 liter of water @ 7 days interval, T_7= Spraying of Malathion 57 EC @ 1 ml mixed with 1 liter of water @ 7 days interval, T_8= Untreated control]

From the above findings it was revealed that the lowest fruit infestation (14.67%) (number) was recorded in treatment T_2 using the poison bait trap in the field, where the highest reduction of fruit infestation over control was 83.20%. As a result, the order of efficacy of management practices in terms of fruit infestation reduction(number) is $T_2>T_1>T_3>T_7>T_5>T_6>T_4>T_8$.

4.3.2. Fruit infestation(weight)

4.3.2.1. Early fruiting stage

The effect of management practices on fruit infestation (weight) at early fruiting stage has been shown in Table 4.3.4. Significant variations were observed among the treatments in terms of cucurbit fruit fly infestation on bitter gourd. The highest weight of fruit plot^{-1} (661.7 g/plot) was recorded in treatment T_2, that is statistically different from others, followed by T_1 (466.7 g/plot), T_3 (425.3 g/plot) and T_7 (417.0 g/plot). On the other hand, the lowest weight of fruit plot^{-1} (269.7 g/plot) was recorded in treatment T_8, which is statistically different from all other treatments, followed by T_4 (306.7 g/plot), T_6 (324.0 g/plot) and T_5 (381.7 g/plot).

The lowest weight of infested fruit plot^{-1} (127.7 g/plot) was recorded in treatment T_2, which is statistically different from others, followed by T_1 (137.7 g/plot), T_3 (147.7 g/plot). And the highest weight of infested fruit plot^{-1} (244.7 g/plot) was recorded in treatment T_8, which was statistically different from others, followed by T_4(232.3 g/plot), T_6(210.7 g/plot), T_5(190.7 g/plot) and T_7(165.3 g/plot) (Table 4.3.4).

Considering the level of infestation, the lowest fruit infestation (19.30%)(weight) was recorded in treatment T_2, which is statistically different from all other treatments, followed by T_1 (29.50%), T_3 (34.72%) and T_7 (39.65%). On the other hand, the highest fruit infestation (weight)

was recorded in treatment T_8 (90.73%), which is statistically different from all other treatments, followed by T_4 (75.76%), T_6 (65.02%) and T_5 (49.96%) (Table 4.3.4).

Considering the reduction of fruit infestation (weight), the highest reduction of fruit infestation (weight) over control was observed (78.73%) in treatment T_2, followed by T_1 (67.49%), T_3 (61.73%) and T_7 (56.30%). Whereas the lowest reduction of fruit infestation (weight) over control was observed in treatment T_4 (16.50%), T_6 (28.34%) and T_5 (44.94%) (Table 4.3.4).

Table 4.3.4. Effect of management practices on fruit infestation (weight) at early fruiting stage

Treatment	% fruit infestation (weight) at early fruiting stage			
	Total wt. of fruit plot^{-1} (gm)	Wt. of infested fruit plot^{-1} (gm)	% fruit infestation	% reduction of fruit infestation over control
T_1	466.7 b	137.7 g	29.50 g	67.49
T_2	661.7 a	127.7 h	19.30 h	78.73
T_3	425.3 c	147.7 f	34.72 f	61.73
T_4	306.7 g	232.3 b	75.76 b	16.50
T_5	381.7 e	190.7 d	49.96 d	44.94
T_6	324.0 f	210.7 c	65.02 c	28.34
T_7	417.0 d	165.3 e	39.65 e	56.30
T_8	269.7 h	244.7 a	90.73 a	0.00
CV(%)	0.94	0.88	0.80	-
$LSD_{(0.05)}$	6.46	2.72	0.68	-

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT). Here, T1= Setting up of pheromone trap replaced at 1 month interval, T2= Setting up of poison bait trap @ 2 gm Sevin 85 WP mixed with 100 g mashed sweet gourd and 10 ml molasses replaced at 4 days interval, T3= Bait spray @ 10 ml molasses and 1 ml Malathion mixed with 1 liter of water @ 7 days interval, T4= Spraying of spinosad @ 0.08 ml per liter of water at 7 days interval, T5= Spraying of neem oil @ 3 ml neem oil and 10 ml Trix mixed with 1 liter of water @ 7 days interval, T6= Spraying of neem seed kernel extract @ 3 ml neem seed kernel extract and 10 ml Trix mixed with 1 liter of water @ 7 days interval, T7= Spraying of Malathion 57 EC @ 1 ml mixed with 1 liter of water @ 7 days interval, T8= Untreated control]

From the above findings it was revealed that, the lowest fruit infestation (19.30%)(weight) was recorded in treatment T_2, using the poison bait trap in the field, where the highest reduction of fruit infestation (weight) over control was 78.73%. As a result, the order of efficacy of management practices in terms of fruit infestation (weight) reduction is $T_2>T_1>T_3>T_7>T_5>T_6>T_4>T_8$.

4.3.2.2. Mid fruiting stage

The effect of management practices on fruit infestation (weight) at mid fruiting stage has been shown in Table 4.3.5. Significant variations were observed among the treatments in terms of cucurbit fruit fly infestation on bitter gourd. The highest weight of fruit plot^{-1} (1655.67 g/plot) was recorded in treatment T_2, that is statistically different from others, followed by T_1 (1310.67 g/plot), T_3 (1221.67 g/plot) and T_7 (1091.33 g/plot). On the other hand, the lowest weight of fruit plot^{-1} (663.70 g/plot) was recorded in treatment T_8, which is statistically different from all other treatments, followed by T_4 (877.70 g/plot), T_6 (900.30 g/plot) and T_5 (918.30 g/plot).

The lowest weight of infested fruit plot^{-1} (102.33 g/plot) was recorded in treatment T_2, which is statistically similar with T_1 (114.33 g/plot), followed by T_3 (133.33g/plot). And the highest weight of infested fruit plot^{-1} (545.67 g/plot) was recorded in treatment T_8, which was statistically different from others, followed by T_4(314.67 g/plot), T_6(280.67 g/plot), T_5(274.67 g/plot) and T_7(250.67 g/plot) (Table 4.3.5).

Considering the level of infestation, the lowest fruit infestation (6.18%) (weight) was recorded in treatment T_2, which is statistically different from all other treatments, followed by T_1 (8.72%), T_3 (10.91%) and T_7 (22.97%). On the other hand, the highest fruit infestation (weight) was recorded in treatment T_8 (82.18%), which is statistically different from all other treatments, followed by T_4 (35.85%), T_6 (31.17%) and T_5 (29.91%) (Table 4.3.5).

Considering the reduction of fruit infestation (weight), the highest reduction of fruit infestation (weight) over control was observed (92.48%) in treatment T_2, followed by T_1 (89.39%), T_3 (86.72%) and T_7 (72.05%). Whereas the lowest reduction of fruit infestation (weight) over control was observed in T_4 (56.38%), T_6 (62.07%) and T_5 (63.60%) (Table 4.3.5).

Table 4.3.5. Effect of management practices on fruit infestation (weight) at mid fruiting stage

Treatment	% fruit infestation (weight) at mid fruiting stage			
	Total wt. of fruit plot^{-1} (gm)	Wt. of infested fruit plot^{-1} (gm)	% fruit infestation	% reduction of fruit infestation over control
T_1	1310.67 b	114.33 g	8.72 g	89.39
T_2	1655.67 a	102.33 h	6.18 h	92.48
T_3	1221.67 c	133.33 f	10.91 f	86.72
T_4	877.70 g	314.67 b	35.85 b	56.38
T_5	918.30 e	274.67 d	29.91 d	63.60
T_6	900.30 f	280.67 c	31.17 c	62.07
T_7	1091.33 d	250.67 e	22.97 e	72.05
T_8	663.70 h	545.67 a	82.18 a	0.00
CV(%)	0.23	0.84	0.71	-
$LSD_{(0.05)}$	4.12	3.33	0.31	-

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT). Here, T1= Setting up of pheromone trap replaced at 1 month interval, T2= Setting up of poison bait trap @ 2 gm Sevin 85 WP mixed with 100 g mashed sweet gourd and 10 ml molasses replaced at 4 days interval, T3= Bait spray @ 10 ml molasses and 1 ml Malathion mixed with 1 liter of water @ 7 days interval, T4= Spraying of spinosad @ 0.08 ml per liter of water at 7 days interval, T5= Spraying of neem oil @ 3 ml neem oil and 10 ml Trix mixed with 1 liter of water @ 7 days interval, T6= Spraying of neem seed kernel extract @ 3 ml neem seed kernel extract and 10 ml Trix mixed with 1 liter of water @ 7 days interval, T7= Spraying of Malathion 57 EC @ 1 ml mixed with 1 liter of water @ 7 days interval, T8= Untreated control]

From this findings it was revealed that, the lowest fruit infestation (6.18%) (weight) was recorded in treatment T_2, using the poison bait trap in the field, where the highest reduction of fruit infestation (weight) over control was 92.48%. As a result, the order of efficacy of management practices in terms of fruit infestation (weight) reduction is $T_2>T_1>T_3>T_7>T_5>T_6>T_4>T_8$.

4.3.2.3. Late fruiting stage

The effect of management practices on fruit infestation (weight) at late fruiting stage has been shown in Table 4.3.6. Significant variations were observed among the treatments in terms of fruit fly infestation on bitter gourd. The highest weight of fruit plot^{-1} (1023.67 g/plot) was recorded in treatment T_2, followed by T_1 (945.67 g/plot), T_3 (843.33 g/plot) and T_7 (821.33 g/plot). On the other hand, the lowest weight of fruit plot^{-1} (515.67 g/plot) was recorded in treatment T_8, which

is statistically different from all other treatments, followed by T_4 (566.67 g/plot), T_6 (645.67 g/plot) and T_5 (716.33 g/plot).

The lowest weight of infested fruit plot^{-1} (122.67 g/plot) was recorded in treatment T_2, which is statistically different from other treatments, followed by T_1 (170.67 g/plot), T_3 (177.33g/plot). And the highest weight of infested fruit plot^{-1} (462.33 g/plot) was recorded in treatment T_8, which was statistically different from others, followed by T_4(334.67 g/plot), T_6(292.67 g/plot), T_5(244.67 g/plot) and T_7(209.33 g/plot) (Table 4.3.6).

Considering the level of infestation, the lowest fruit infestation (11.98%) (weight) was recorded in treatment T_2, followed by T_1 (18.05%), T_3 (21.03%) and T_7 (25.49%). On the other hand, the highest fruit infestation (weight) was recorded in treatment T_8 (89.60%), followed by T_4 (59.06%), T_6 (45.33%) and T_5 (34.16%) (Table 4.3.6).

Considering the reduction of fruit infestation (weight), the highest reduction of fruit infestation (weight) over control was observed (86.63%) in treatment T_2, followed by T_1 (79.85%), T_3 (76.53%) and T_7 (71.55%). Whereas the lowest reduction of fruit infestation (weight) over control was observed in treatment T_4 (34.08%), followed by T_6 (49.41%) and T_5 (61.88%) (Table 4.3.6).

Table 4.3.6. Effect of management practices on fruit infestation (weight) at late fruiting stage

Treatment	% fruit infestation(weight) at late fruiting stage			
	Total wt. of fruit plot^{-1} (gm)	**Wt. of infested fruit plot^{-1} (gm)**	**% fruit infestation**	**% reduction of fruit infestation over control**
T_1	945.67 b	170.67 g	18.05 g	79.85
T_2	1023.67 a	122.67 h	11.98 h	86.63
T_3	843.33 c	177.33 f	21.03 f	76.53
T_4	566.67 g	334.67 b	59.06 b	34.08
T_5	716.33 e	244.67 d	34.16 d	61.88
T_6	645.67 f	292.67 c	45.33 c	49.41
T_7	821.33 d	209.33 e	25.49 e	71.55
T_8	515.67 h	462.33 a	89.60 a	0.00
CV(%)	0.26	0.83	0.61	-

$LSD_{(0.05)}$	3.30	3.55	0.39	-

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT). Here, T1= Setting up of pheromone trap replaced at 1 month interval, T2= Setting up of poison bait trap @ 2 gm Sevin 85 WP mixed with 100 g mashed sweet gourd and 10 ml molasses replaced at 4 days interval, T3= Bait spray @ 10 ml molasses and 1 ml Malathion mixed with 1 liter of water @ 7 days interval, T4= Spraying of spinosad @ 0.08 ml per liter of water at 7 days interval, T5= Spraying of neem oil @ 3 ml neem oil and 10 ml Trix mixed with 1 liter of water @ 7 days interval, T6= Spraying of neem seed kernel extract @ 3 ml neem seed kernel extract and 10 ml Trix mixed with 1 liter of water @ 7 days interval, T7= Spraying of Malathion 57 EC @ 1 ml mixed with 1 liter of water @ 7 days interval, T8= Untreated control]

From the above findings it was revealed that, the lowest fruit infestation (11.98%) (weight) was recorded in treatment T_2, using the poison bait trap in the field, where the highest reduction of fruit infestation (weight) over control was 86.63%. As a result, the order of efficacy of management practices in terms of fruit infestation (weight) reduction is $T_2>T_1>T_3>T_7>T_5>T_6>T_4>T_8$.

4.3.3. Percent edible portion of infested fruit

4.3.3.1. Early fruiting stage

The effect of management practices on the percent edible portion of infested fruit at early fruiting stage has been shown in Table 4.3.7. Significant variations were observed among the treatments in terms of cucurbit fruit fly infestation on bitter gourd. The highest percent edible portion of infested bitter gourd was recorded in treatment T_2 (66.58%), that was statistically different from others, followed by T_1 (54.48%), T_3 (42.44%) and T_7 (34.69%). On the other hand, the lowest percent edible portion of infested bitter gourd was recorded in treatment T_8 (9.95%), which was statistically different from others, followed by T_4 (15.64%), T_6 (20.74%) and T_5 (26.92%) (Table 4.3.7).

Considering the increase of percent edible portion of infested bitter gourd, the highest increase of percent edible portion of infested bitter gourd over control was observed (569.15%) in treatment T_2, followed by T_1 (447.54%), T_3 (326.53%) and T_7 (248.64%). Whereas the lowest increase of

percent edible portion of infested bitter gourd over control was recorded in treatment T_4 (57.19%), followed by T_6 (108.44%) and T_5 (170.55%) (Table 4.3.7).

Table 4.3.7. Effect of management practices on percent edible portion of infested bitter gourd at early fruiting stage

Treatment	Weight of edible portion of infested fruit plot^{-1} (gm)	% edible portion	% increase over control
T_1	75.00 b	54.48 b	447.54
T_2	85.00 a	66.58 a	569.15
T_3	62.67 c	42.44 c	326.53
T_4	36.33 d	15.64 g	57.19
T_5	51.33 d	26.92 e	170.55
T_6	43.67 e	20.74 f	108.44
T_7	57.33 cd	34.69 d	248.64
T_8	24.33 g	9.95 h	0.00
CV(%)	6.60	6.41	-
$LSD_{(0.05)}$	6.07	3.67	-

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT). Here, T1= Setting up of pheromone trap replaced at 1 month interval, T2= Setting up of poison bait trap @ 2 gm Sevin 85 WP mixed with 100 g mashed sweet gourd and 10 ml molasses replaced at 4 days interval, T3= Bait spray @ 10 ml molasses and 1 ml Malathion mixed with 1 liter of water @ 7 days interval, T4= Spraying of spinosad @ 0.08 ml per liter of water at 7 days interval, T5= Spraying of neem oil @ 3 ml neem oil and 10 ml Trix mixed with 1 liter of water @ 7 days interval, T6= Spraying of neem seed kernel extract @ 3 ml neem seed kernel extract and 10 ml Trix mixed with 1 liter of water @ 7 days interval, T7= Spraying of Malathion 57 EC @ 1 ml mixed with 1 liter of water @ 7 days interval, T8= Untreated control]

From the above findings it was revealed that, the highest percent edible portion of infested bitter gourd (66.58%) was recorded in treatment T_2 using the poison bait trap in the field, where the highest increase of percent edible portion of infested bitter gourd over control was 569.15%. As a result, the order of efficacy in terms of increase the percent edible portion of infested bitter gourd fruit at early fruiting stage is $T_2>T_1>T_3>T_7>T_5>T_6>T_4>T_8$.

4.3.3.2. Mid fruiting stage

The effect of management practices on the percent edible portion of infested fruit at mid fruiting stage has been shown in Table 4.3.8. Significant variations were observed among the treatments

in terms of cucurbit fruit fly infestation on bitter gourd. The highest percent edible portion of infested bitter gourd was recorded in treatment T_2 (75.25%), that was statistically different from all other treatments, followed by T_1 (60.64%), T_3 (75.25%) and T_7 (20.22%). On the other hand, the lowest percent edible portion of infested bitter gourd was recorded in treatment T_8 (6.38%), which was statistically different from others, followed by T_4 (10.48%), T_6 (14.36%) and T_5 (16.39%) (Table 4.3.8).

Considering the increase of percent edible portion of infested bitter gourd, the highest increase of percent edible portion of infested bitter gourd over control was observed (1079.47%) in treatment T_2, followed by T_1 (850.47%), T_3 (609.40%) and T_7 (216.93%). Whereas the lowest increase of percent edible portion of infested bitter gourd over control was recorded in treatment T_4 (64.26%), followed by T_6 (125.08%) and T_5 (156.90%) (Table 4.3.8).

Table 4.3.8. Effect of management practices on percent edible portion of infested bitter gourd at mid fruiting stage

Treatment	Weight of edible portion of infested fruit plot^{-1} (gm)	% edible portion	% increase over control
T_1	69.33 b	60.64 b	850.47
T_2	77.00 a	75.25 a	1079.47
T_3	60.33 c	45.26 c	609.40
T_4	33.00 g	10.48 f	64.26
T_5	45.00 e	16.39 e	156.90
T_6	40.33 f	14.36 e	125.08
T_7	50.67 d	20.22 d	216.93
T_8	26.33 h	6.38 g	0.00
CV(%)	3.53	6.72	-
$LSD_{(0.05)}$	2.99	3.53	-

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT). Here, T1= Setting up of pheromone trap replaced at 1 month interval, T2= Setting up of poison bait trap @ 2 gm Sevin 85 WP mixed with 100 g mashed sweet gourd and 10 ml molasses replaced at 4 days interval, T3= Bait spray @ 10 ml molasses and 1 ml Malathion mixed with 1 liter of water @ 7 days interval, T4= Spraying of spinosad @ 0.08 ml per liter of water at 7 days interval, T5= Spraying of neem oil @ 3 ml neem oil and 10 ml Trix mixed with 1 liter of water @ 7 days interval, T6= Spraying of neem seed kernel extract @ 3 ml neem seed kernel extract and 10 ml Trix mixed with 1 liter of water @ 7 days interval, T7= Spraying of Malathion 57 EC @ 1 ml mixed with 1 liter of water @ 7 days interval, T8= Untreated control]

From the above findings it was revealed that, the highest percent edible portion of infested bitter gourd (75.25%) was recorded in treatment T_2 using the poison bait trap in the field, where the highest increase of percent edible portion of infested bitter gourd over control was 1079.47%. As a result, the order of efficacy in terms of increase the percent edible portion of infested bitter gourd fruit at mid fruiting stage is $T_2>T_1>T_3>T_7>T_5>T_6>T_4>T_8$.

4.3.3.3. Late fruiting stage

The effect of management practices on the percent edible portion of infested fruit at late fruiting stage has been shown in Table 4.3.9. Significant variations were observed among the treatments in terms of cucurbit fruit fly infestation on bitter gourd. The highest percent edible portion of infested bitter gourd was recorded in treatment T_2 (75.84%), that was statistically different from all other treatments, followed by T_1 (51.18%), T_3 (45.49%) and T_7 (34.88%). On the other hand, the lowest percent edible portion of infested bitter gourd was recorded in T_8 (8.87%), which was statistically different from others, followed by T_4 (15.64%), T_6 (21.53%) and T_5 (28.74%) (Table 4.3.9).

Considering the increase of percent edible portion of infested bitter gourd, the highest increase of percent edible portion of infested bitter gourd over control was observed (755.02%) in treatment T_2, followed by T_1 (477.00%), T_3 (412.85%) and T_7 (293.24%). Whereas the lowest increase of percent edible portion of infested bitter gourd over control was recorded in treatment T_4 (76.32%), followed by T_6 (142.73%) and T_5 (224.01%) (Table 4.3.9).

Table 4.3.9. Effect of management practices on percent edible portion of infested bitter gourd at late fruiting stage

Treatment	Weight of edible portion of infested fruit plot^{-1} (gm)	% edible portion	% increase over control
T_1	87.33 a	51.18 b	477.00
T_2	93.00 a	75.84 a	755.02
T_3	80.67 b	45.49 c	412.85
T_4	52.33 e	15.64 g	76.32

T_5	70.33 c	28.74 e	224.01
T_6	63.00 d	21.53 f	142.73
T_7	73.00 c	34.88 d	293.24
T_8	41.00 f	8.87 h	0.00
CV(%)	4.86	3.96	-
$LSD_{(0.05)}$	5.75	2.36	-

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT). Here, T1= Setting up of pheromone trap replaced at 1 month interval, T2= Setting up of poison bait trap @ 2 gm Sevin 85 WP mixed with 100 g mashed sweet gourd and 10 ml molasses replaced at 4 days interval, T3= Bait spray @ 10 ml molasses and 1 ml Malathion mixed with 1 liter of water @ 7 days interval, T4= Spraying of spinosad @ 0.08 ml per liter of water at 7 days interval, T5= Spraying of neem oil @ 3 ml neem oil and 10 ml Trix mixed with 1 liter of water @ 7 days interval, T6= Spraying of neem seed kernel extract @ 3 ml neem seed kernel extract and 10 ml Trix mixed with 1 liter of water @ 7 days interval, T7= Spraying of Malathion 57 EC @ 1 ml mixed with 1 liter of water @ 7 days interval, T8= Untreated control]

From the above findings it was revealed that, the highest percent edible portion of infested bitter gourd (75.84%) was recorded in treatment T_2 using the poison bait trap in the field, where the highest increase of percent edible portion of infested bitter gourd over control was 88.30%. As a result, the order of efficacy in terms of increase the percent edible portion of infested bitter gourd fruit at late fruiting stage is $T_2>T_1>T_3>T_7>T_5>T_6>T_4>T_8$.

4.3.4. Effect of management practices on the yield attributes of bitter gourd

4.3.4.1. Single fruit weight

The effect of management practices on single fruit weight has been shown in Table 4.3.10. Significant variations were observed among the treatments in terms of single fruit weight of bitter gourd. The highest single fruit weight (86.04g) was recorded in treatment T_2, which is statistically different from others, followed by T_1 (80.40g), T_3 (74.40g) and T_7 (70.80g). On the other hand, the lowest single fruit weight was recorded in treatment T_8 (42.93g), followed by T_4 (52.67g), T_6 (56.27g) and T_5 (68.93g) (Table 4.3.10).

The maximum increase of single fruit weight over control (100.42%) was observed in treatment T_2, followed by T_1 (87.28%), T_3 (73.31%) and T_7 (64.92%). Whereas the minimum increase of single fruit weight over control was observed in treatment T_4 (22.69%), followed by T_6 (31.07%) and T_5 (60.56%) (Table 4.3.10).

From the above findings it was revealed that, the highest single fruit weight (86.04g) was recorded in treatment T_2 using the poison bait trap in the field, where the highest increase of single fruit weight over control was 100.42%. As a result, the order of efficacy in increasing single fruit weight of bitter gourd is T_2>T_1>T_3> T_7> T_5> T_6> T_4> T_8.

4.3.4.2. Number of fruit plot^{-1}

The effect of management practices on number of fruit plot^{-1} has been shown in Table 4.3.10. Significant variations were observed among the treatments in terms of number of fruit plot^{-1} of bitter gourd. The highest number of fruit plot^{-1} (62.33 fruits/plot) was recorded in treatment T_2, followed by T_1 (50.00 fruits/plot), T_3 (48.00 fruits/plot) and T_7 (44.67 fruits/plot). On the other hand, the lowest number of fruit plot^{-1} (32.00 fruits/plot) was found in treatment T_8, which is statistically different from all other treatments, followed by T_4 (36.00 fruits/plot), T_6 (40.00 fruits/plot) and T_5 (42.33 fruits/plot) (Table 4.3.10).

The maximum increase of number of fruit plot^{-1} over control (94.78%) was observed in treatment T_2, followed by T_1 (56.25%), T_3 (50.00%) and T_7 (39.59%). Whereas the minimum increase of number of fruits plot^{-1} over control was observed in treatment T_4 (12.50%), followed by T_6 (25.00%) and T_5 (32.28%) (Table 4.3.10).

Table 4.3.10. Effect of management practices on the yield attributes of bitter gourd

Treatment	Single fruit weight plot^{-1} (gm)	% increase over control	Number of fruit plot^{-1}	% increase over control
T_1	80.40 b	87.28	50.00 b	56.25
T_2	86.04 a	100.42	62.33 a	94.78
T_3	74.40 c	73.31	48.00 b	50.00
T_4	52.67 e	22.69	36.00 f	12.50
T_5	68.93 d	60.56	42.33 d	32.28
T_6	56.27 e	31.07	40.00 e	25.00
T_7	70.80 cd	64.92	44.67 c	39.59
T_8	42.93 f	0.00	32.00 g	0.00
CV(%)	4.50	-	2.93	-
$LSD_{(0.05)}$	5.06	-	2.20	-

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT). Here, T1= Setting up of pheromone trap replaced at 1 month interval, T2= Setting up of poison bait trap @ 2 gm Sevin 85 WP mixed with 100 g mashed sweet gourd and 10 ml molasses replaced at 4 days interval, T3= Bait spray @ 10 ml molasses and 1 ml Malathion mixed with 1 liter of water @ 7 days interval, T4= Spraying of spinosad @ 0.08 ml per liter of water at 7 days interval, T5= Spraying of neem oil @ 3 ml neem oil and 10 ml Trix mixed with 1 liter of water @ 7 days interval, T6= Spraying of neem seed kernel extract @ 3 ml neem seed kernel extract and 10 ml Trix mixed with 1 liter of water @ 7 days interval, T7= Spraying of Malathion 57 EC @ 1 ml mixed with 1 liter of water @ 7 days interval, T8= Untreated control]

From the above findings it was revealed that, the highest single fruit weight plot^{-1} and number of fruitplot^{-1} (86.04 gm and 62.33 fruits/ plot, respectively) was recorded in treatment T_2 using the poison bait trap in the field, where the maximum increase of single fruit weight plot^{-1} over control was 100.42% and the maximum number of fruit plot^{-1} was 94.78%. As a result, the order of efficacy in increasing the girth of healthy bitter gourd is T_2>T_1>T_3> T_7> T_5> T_6> T_4> T_8.

4.3.5. Length and girth of single healthy fruit

4.3.5.1. Length of fruit

The effect of management practices on length of healthy fruit of bitter gourd has been shown in Table 4.3.11. Significant variations were observed among the treatments in terms of length of healthy fruits. The highest length (20.66 cm) of bitter gourd was recorded in treatment T_2, that is statistically similar with T_1 (20.19 cm) and T_3 (19.67 cm). On the other hand the lowest length of healthy bitter gourd was recorded in treatment T_8 (15.10 cm), followed by T_4 (16.84 cm), T_6 (18.00 cm) and T_5 (18.29 cm) (Table 4.3.11).

Considering the increase of fruit length, the maximum increase of bitter gourd length over control (36.82%) was observed in treatment T_2, which was followed by T_1 (33.71%), T_3 (30.26%) and T_7 (24.04%). Whereas the minimum increase of fruit length over control was observed in treatment T_4 (11.52%), followed by T_6 (19.21%) and T_5 (21.13%) (Table 4.3.11).

From the above findings it was revealed that, the highest healthy bitter gourd length (20.66 cm) was recorded in treatment T_2 using the poison bait trap in the field, where the maximum increase

of fruit length over control was 36.82%. As a result, the order of efficacy in increasing healthy bitter gourd length is T_2>T_1>T_3> T_7> T_5> T_6> T_4> T_8.

4.3.5.2. Girth of fruit

The effect of management practices on girth of healthy fruit of bitter gourd has been shown in Table 4.3.11. Significant variations were observed among the treatments in terms of girth of healthy fruits. The highest girth (12.64 cm) of bitter gourd was recorded in treatment T_2, which is statistically similar with T_1 (12.07 cm) and followed by T_3 (11.75 cm) and T_7 (11.29 cm). On the other hand the lowest girth of healthy bitter gourd was recorded in treatment T_8 (9.91 cm), which is statistically similar with T_4 (10.41 cm) and followed by T_6 (10.90 cm) and T_5 (11.01 cm) (Table 4.3.11).

Considering the increase of fruit length, the maximum increase of fruit girth over control (27.55%) was recorded in treatment T_2, which was followed by T_1 (21.80%), T_3 (18.57%) and T_7 (13.93%). Whereas the minimum increase of fruit girth over control was observed in T_4 (5.05%), followed by T_6 (9.99%) and T_5 (11.10%) (Table 4.3.11).

Table 4.3.11. Effect of management practices on the yield attributes of bitter gourd

Treatment	Length of single healthy fruit plot^{-1} (cm)	% increase over control	Girth of single healthy fruit plot^{-1} (cm)	% increase over control
T_1	20.19 a	33.71	12.07 ab	21.80
T_2	20.66 a	36.82	12.64 a	27.55
T_3	19.67 ab	30.26	11.75 bc	18.57
T_4	16.84 d	11.52	10.41 ef	5.05
T_5	18.29 c	21.13	11.01 de	11.10
T_6	18.00 c	19.21	10.90 de	9.99
T_7	18.73 bc	24.04	11.29 cd	13.93
T_8	15.10 e	0.00	9.91 f	0.00
CV(%)	3.46	-	3.24	-

$LSD_{(0.05)}$	1.08	-	0.62	-

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT). Here, T1= Setting up of pheromone trap replaced at 1 month interval, T2= Setting up of poison bait trap @ 2 gm Sevin 85 WP mixed with 100 g mashed sweet gourd and 10 ml molasses replaced at 4 days interval, T3= Bait spray @ 10 ml molasses and 1 ml Malathion mixed with 1 liter of water @ 7 days interval, T4= Spraying of spinosad @ 0.08 ml per liter of water at 7 days interval, T5= Spraying of neem oil @ 3 ml neem oil and 10 ml Trix mixed with 1 liter of water @ 7 days interval, T6= Spraying of neem seed kernel extract @ 3 ml neem seed kernel extract and 10 ml Trix mixed with 1 liter of water @ 7 days interval, T7= Spraying of Malathion 57 EC @ 1 ml mixed with 1 liter of water @ 7 days interval, T8= Untreated control]

From the above findings it was revealed that, the highest single healthy bitter gourd length (20.66 cm) and girth (12.64 cm) were recorded in treatment T_2 using the poison bait trap in the field, where the maximum increase of fruit length and girth over control were36.82% and 27.55%, respectively. As a result, the order of efficacy in increasing the girth of healthy bitter gourd is T_2>T_1>T_3> T_7> T_5> T_6> T_4> T_8.

4.3.6. Length and girth of single infested fruit

4.3.6.1. Length of infested fruit

The effect of management practices on length of infested fruit of bitter gourd has been shown in Table 3.4.12. Significant variations were recorded among the treatments in terms of length of infested fruits. The highest length (17.99 cm) of infested bitter gourd was recorded in treatment T_2, that is statistically similar with T_1 (17.26 cm) and followed by T_3 (16.87 cm) and T_7 (16.49 cm). On the other hand, the lowest length of infested bitter gourd was recorded in treatment T_8 (13.65 cm), which is statistically different from others, followed by T_4 (15.26 cm), T_6 (15.69 cm) and T_5 (16.04 cm) (Table 3.4.12).

Considering the increase of fruit length, the maximum percentage of fruit length increase over control (31.79%) was observed in T_2, which was followed by T_1 (26.45%), T_3 (23.59%) and T_7 (20.81%). Whereas the minimum increase of infested fruit length over control was observed in treatment T_4 (11.79%), followed by T_6 (14.95%) and T_5 (17.51%) (Table 3.4.12).

From the above findings it was revealed that, the highest infested fruit length (17.99 cm) was recorded in T_2 using the poison bait trap in the field, where the maximum increase of fruit length over control was 31.79%. As a result, the order of efficacy in increasing the length of infested bitter gourd is T_2>T_1>T_3> T_7> T_5> T_6> T_4> T_8.

4.3.6.2. Girthof infested fruit

The effect of management practices on girth of infested fruit of bitter gourd has been shown in Table 3.4.12. Significant variations were observed among the treatments in terms of girth of infested fruits. The highest girth of bitter gourd (11.20 cm) was recorded in treatment T_2, that is statistically similar with T_1 (10.85 cm), followed by T_3 (10.52 cm) and T_7 (10.17 cm). On the other hand the lowest girth of infested bitter gourd was recorded in treatment T_8 (8.85 cm), which is statistically similar with T_4 (9.18 cm) and T_6 (9.32 cm), followed by T_5 (9.79 cm) (Table 3.4.12).

The maximum increase of infested fruit girth over control (26.55%) was recorded in treatment T_2, followed by T_1 (22.60%), T_3 (26.55%) and T_7 (14.92%). Whereas the minimum increase of infested fruit girth over control was observed in T_4 (3.73%), followed by T_6 (5.31%) and T_5 (10.62%) (Table 3.4.12).

Table 4.3.12. Effect of management practices on the yield attributes of bitter gourd

Treatment	Length of single infested fruit plot^{-1} (cm)	% increase over control	Girth of single infested fruit plot^{-1} (cm)	% increase over control
T_1	17.26 ab	26.45	10.85 ab	22.60
T_2	17.99 a	31.79	11.20 a	26.55
T_3	16.87 bc	23.59	10.52 bc	18.87
T_4	15.26 e	11.79	9.18 ef	3.73
T_5	16.04 cde	17.51	9.79 de	10.62
T_6	15.69 de	14.95	9.32 ef	5.31
T_7	16.49 bcd	20.81	10.17 cd	14.92
T_8	13.65 f	0.00	8.85 f	0.00

CV(%)	2.96	-	3.81	-
$LSD_{(0.05)}$	0.81	-	0.64	-

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT). Here, T1= Setting up of pheromone trap replaced at 1 month interval, T2= Setting up of poison bait trap @ 2 gm Sevin 85 WP mixed with 100 g mashed sweet gourd and 10 ml molasses replaced at 4 days interval, T3= Bait spray @ 10 ml molasses and 1 ml Malathion mixed with 1 liter of water @ 7 days interval, T4= Spraying of spinosad @ 0.08 ml per liter of water at 7 days interval, T5= Spraying of neem oil @ 3 ml neem oil and 10 ml Trix mixed with 1 liter of water @ 7 days interval, T6= Spraying of neem seed kernel extract @ 3 ml neem seed kernel extract and 10 ml Trix mixed with 1 liter of water @ 7 days interval, T7= Spraying of Malathion 57 EC @ 1 ml mixed with 1 liter of water @ 7 days interval, T8= Untreated control]

From the above findings it was revealed that, the highest infested bitter gourd girth (11.20 cm) was recorded in treatment T_2 using the poison bait trap in the field, where the maximum increase of fruit girth over control was 26.55%. As a result, the order of efficacy in increasing the girth of infested bitter gourd is T_2>T_1>T_3> T_7> T_5> T_6> T_4> T_8.

4.3.7.Yield of bitter gourd

The effect of management practices on yield of bitter gourd has been shown in Table 4.3.13. Significant variations were observed among the treatments in terms of yield of bitter gourd. The highest yield (5.36 kg/plot) was recorded in treatment T_2, followed by T_1 (4.02 kg/plot), T_3 (3.57 kg/plot), T_7 (3.16 kg/plot) and T_5 (2.92 kg/plot). On the other hand, the lowest yield (1.37 kg/plot) was recorded in treatment T_8, which was statistically different from all other treatments, followed by T_4 (1.89 kg/plot) and T_6 (2.25 kg/plot) (Table 4.3.13).

Considering the yield of bitter gourd in ton/ha, the highest yield (17.87 ton/ha) was recorded in treatment T_2, followed by T_1 (13.40 ton/ha), T_3 (11.91 ton/ha), T_7 (10.54 ton/ha) and T_5 (9.74 ton/ha). On the other hand, the lowest yield (4.58 ton/ha) was recorded in treatment T_8, which was statistically different from all other treatments, followed by T_4 (6.32 ton/ha) and T_6 (7.50 ton/ha) (Table 4.3.13).

Considering the yield increase over control, the maximum increase of yield of bitter gourd over control (290.17%) was recorded in treatment T_2, followed by T_1 (192.58%), T_3 (160.04%) and T_7

(130.13%). Whereas the minimum increase of yield over control (37.99%) was recorded in treatment T_4, followed by T_6 (63.76%) and T_5 (112.66%) (Table 4.3.13).

Table 4.3.13. Effect of management practices on yield of bitter gourd

Treatment	Yield (Kg/plot)	Yield (ton/ha)	% increase over control
T_1	4.02 b	13.40 b	192.58
T_2	5.36 a	17.87 a	290.17
T_3	3.57 c	11.91 c	160.04
T_4	1.89 f	6.32 f	37.99
T_5	2.92 d	9.74 d	112.66
T_6	2.25 e	7.50 e	63.76
T_7	3.16 d	10.54 d	130.13
T_8	1.37 g	4.58 g	0.00
CV(%)	5.30	5.29	-
$LSD_{(0.05)}$	0.81	0.91	-

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT). Here, T1= Setting up of pheromone trap replaced at 1 month interval, T2= Setting up of poison bait trap @ 2 gm Sevin 85 WP mixed with 100 g mashed sweet gourd and 10 ml molasses replaced at 4 days interval, T3= Bait spray @ 10 ml molasses and 1 ml Malathion mixed with 1 liter of water @ 7 days interval, T4= Spraying of spinosad @ 0.08 ml per liter of water at 7 days interval, T5= Spraying of neem oil @ 3 ml neem oil and 10 ml Trix mixed with 1 liter of water @ 7 days interval, T6= Spraying of neem seed kernel extract @ 3 ml neem seed kernel extract and 10 ml Trix mixed with 1 liter of water @ 7 days interval, T7= Spraying of Malathion 57 EC @ 1 ml mixed with 1 liter of water @ 7 days interval, T8= Untreated control]

From this findings it was revealed that, the highest yield (17.87 ton/ha) was produced in treatment T_2 using the poison bait trap in the field, where the maximum increase of yield over control was 290.17%. As a result, the order of efficacy in increasing the yield of bitter gourd is T_2>T_1>T_3> T_7> T_5> T_6> T_4> T_8.

4.3.8. Relationship between fruit infestation and yield of bitter gourd

4.3.8.1. Early fruiting stage

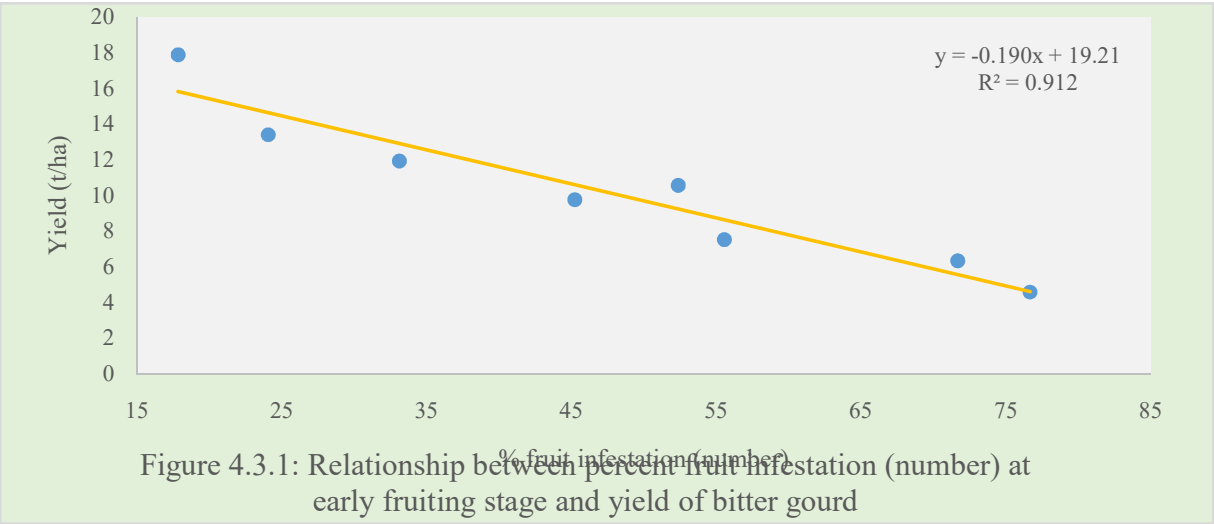

Figure 4.3.1: Relationship between percent fruit infestation (number) at early fruiting stage and yield of bitter gourd

Correlation study was done to establish the relationship between the percent fruit infestation (number) at early fruiting stage and yield (t/ha) of bitter gourd during the management of cucurbit fruit fly. From the study it was revealed that, significant correlation was observed between the fruit infestation and yield of bitter gourd (Figure 4.3.1). It was evident from the Figure 4.3.1 that the regression equation y = -0.1909x + 19.218 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.9128) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a negative relationship between fruit infestation (number) and yield of bitter gourd, i.e., the yield decreased with the increase of the infestation of fruit (number) by cucurbit fruit fly at early fruiting stage.

4.3.8.2. Mid fruiting stage

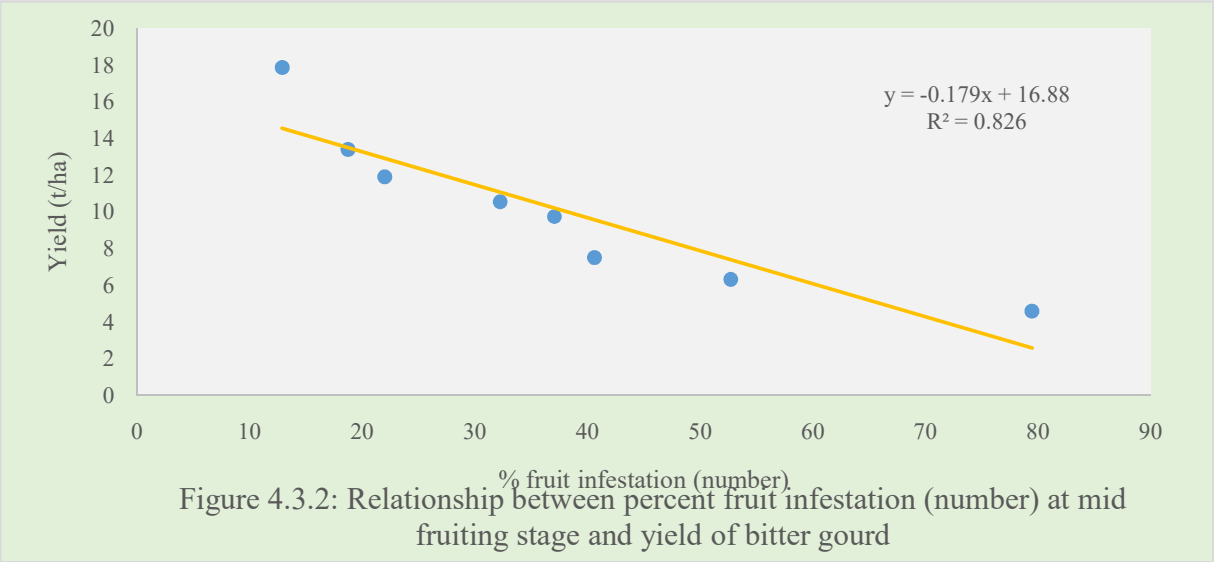

Figure 4.3.2: Relationship between percent fruit infestation (number) at mid fruiting stage and yield of bitter gourd

Correlation study was done to establish the relationship between the percent fruit infestation (number) at mid fruiting stage and yield (t/ha) of bitter gourd during the management of cucurbit fruit fly. From the study it was revealed that, significant correlation was observed between the fruit infestation (number) and yield of bitter gourd (Figure 4.3.2). It was evident from the Figure 4.3.2 that, the regression equation y = -0.1798x + 16.88 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.8262) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a negative relationship between fruit infestation (number) and yield of bitter gourd, i.e., the yield decreased with the increase of the infestation of fruit (number) by cucurbit fruit fly at mid fruiting stage.

4.3.8.3. Late fruiting stage

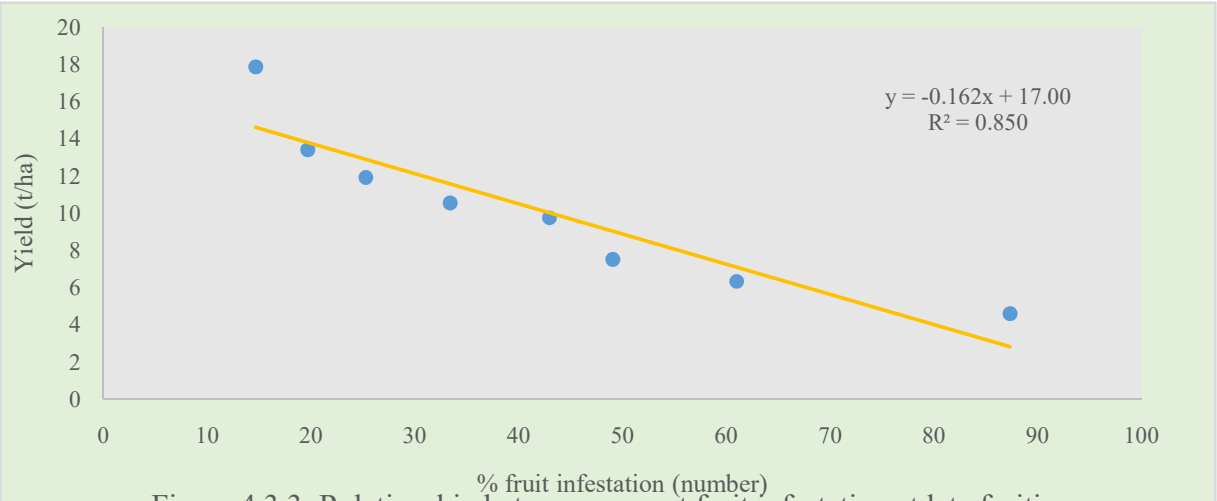

Figure 4.3.3: Relationship between percent fruit infestation at late fruiting stage and yield of bitter gourd

Correlation study was done to establish the relationship between the percent fruit infestation (number) at late fruiting stage and yield (t/ha) of bitter gourd during the management of cucurbit fruit fly. From the study it was revealed that, significant correlation was observed between the fruit infestation (number) and yield of bitter gourd (Figure 4.3.3). It was evident from the Figure 4.3.3 that the regression equation y = -0.1625x + 17.005 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.8502) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a negative relationship between fruit infestation (number) and yield of bitter gourd, i.e., the yield decreased with the increase of the infestation of fruit (number) by cucurbit fruit fly at late fruiting stage.

4.3.9. Relationship between single fruit weight and yield

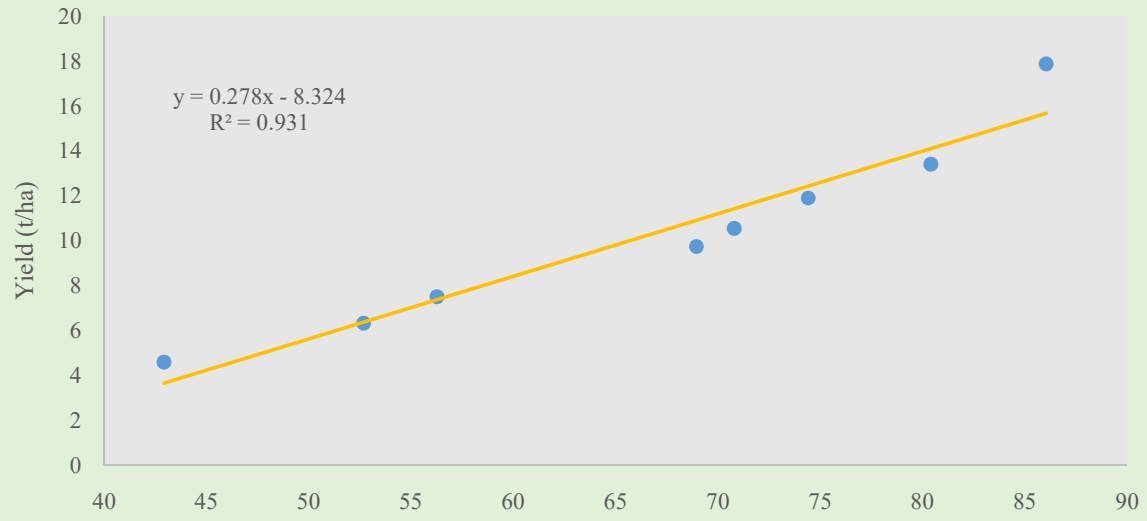

Figure 4.3.4: Relationship between single fruit weight and yield of bitter gourd

Correlation study was done to establish the relationship between the single fruit weight (g) and yield (t/ha) of bitter gourd during the management of cucurbit fruit fly. From the study it was revealed that, significant correlation was observed between the single fruit weight and yield of bitter gourd (Figure 4.3.4). It was evident from the Figure 4.3.4 that, the regression equation y = 0.2788x – 8.3246 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.9319) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a positive relationship between single fruit weight and yield of bitter gourd, i.e., the yield increased with the increase of the single fruit weight.

4.3.10. Relationship between number of fruit per plant and yield

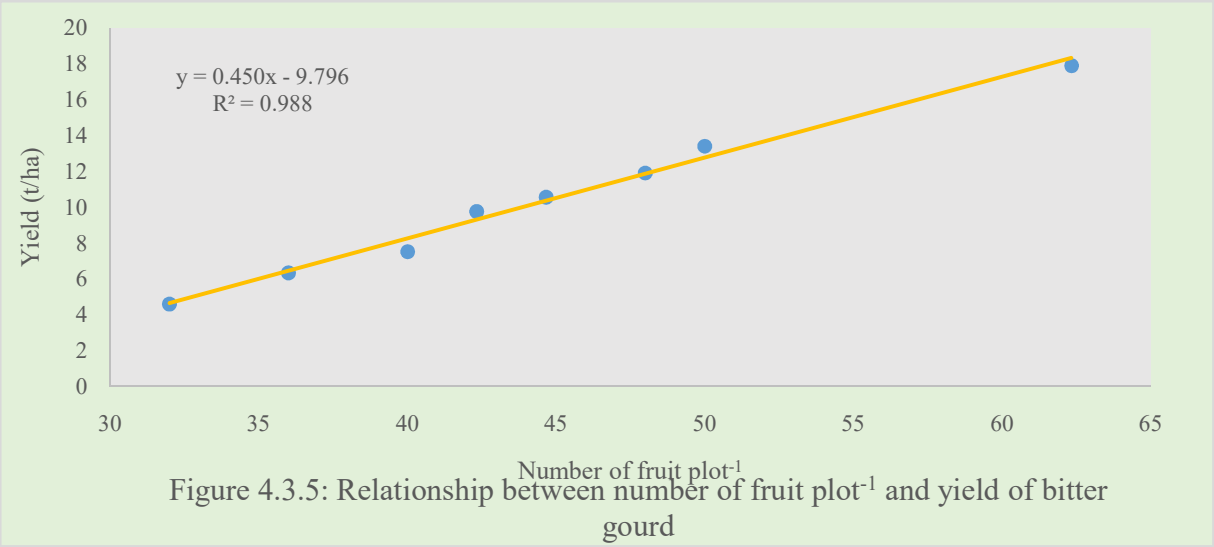

Figure 4.3.5: Relationship between number of fruit plot^{-1} and yield of bitter gourd

Correlation study was done to establish the relationship between the number of fruit plot^{-1} and yield (t/ha) of bitter gourd during the management of cucurbit fruit fly. From the study it was revealed that, significant correlation was observed between the number of fruit plot^{-1} and yield of bitter gourd (Figure 4.3.5). It was evident from the Figure 4.3.5 that, the regression equation y = 0.4509x – 9.7961 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.9887) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis it was evident that, there was a positive relationship between number of fruit plot^{-1} and the yield of bitter gourd, i.e., the yield increased with the increase of the number of fruit plot^{-1}.

4.3.11. Relationship between fruit length and yield

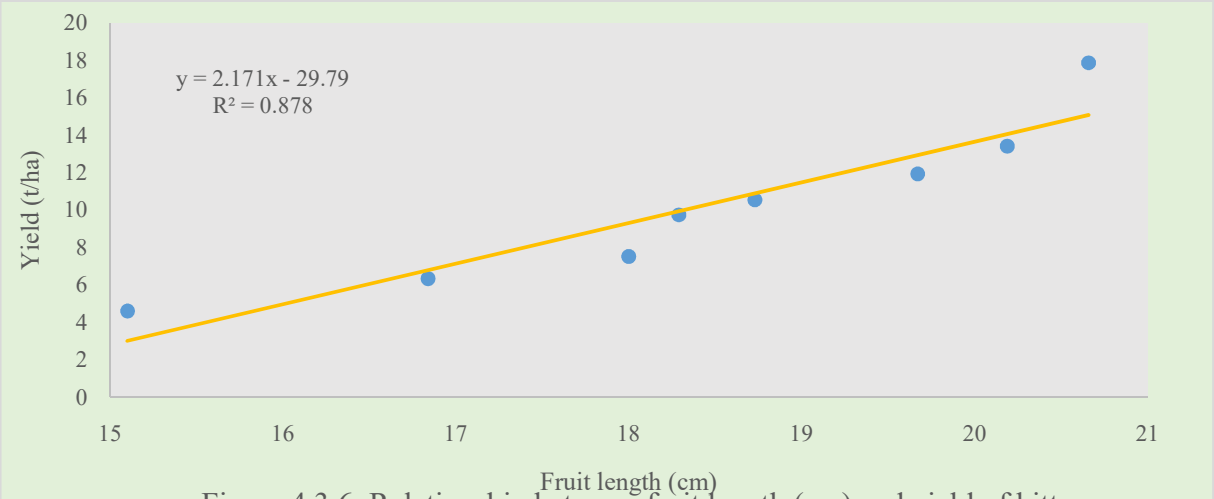

Figure 4.3.6: Relationship between fruit length (cm) and yield of bitter gourd

Correlation study was done to establish the relationship between the fruit length (cm) and yield (t/ha) of bitter gourd during the management of cucurbit fruit fly. From the study it was revealed that, significant correlation was observed between the fruit length and yield of bitter gourd (Figure 4.3.6). It was evident from the Figure 4.3.6 that, the regression equation y = 2.1712x – 29.794 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.8783) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis it was evident that, there was a positive relationship between fruit length and yield of bitter gourd, i.e., the yield increased with the increase of the fruit length.

4.3.12. Relationship between girth of fruit and yield

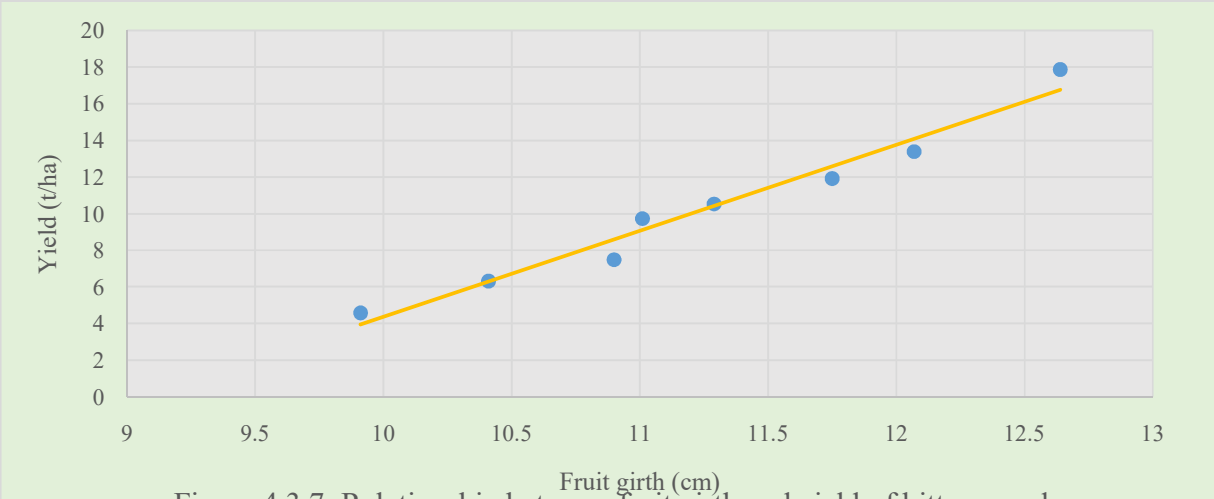

Figure 4.3.7: Relationship between fruit girth and yield of bitter gourd

Correlation study was done to establish the relationship between the girth of fruit (cm) and yield (t/ha) of bitter gourd during the management of cucurbit fruit fly. From the study it was revealed that, significant correlation was observed between the girth of fruit and yield of bitter gourd (Figure 4.3.7). It was evident from the Figure 4.3.7 that, the regression equation y = 4.6954x – 42.579 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.967) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis it was evident that there was a positive relationship between girth of fruit and yield of bitter gourd, i.e., the yield increased with the increase of the girth of single fruit.

4.3.13. Adult fruit fly captured in bait traps and pheromone traps

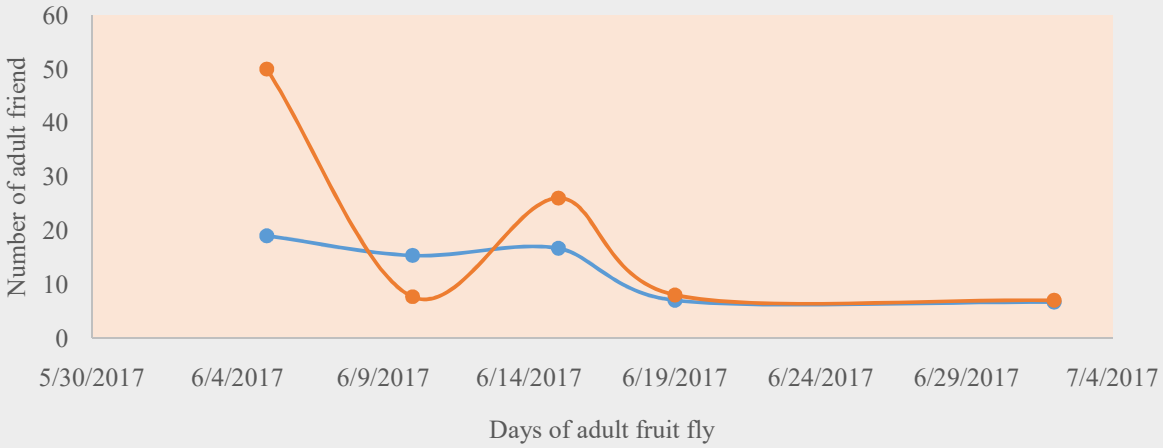

Figure 4.3.8: Number of fruit flies caught by pheromone trap or lightening trap

The efficacy of pheromone trap as compared with poison bait trap in terms of capturing number of adult fruit flies had been assessed in this study. The data as depicted in the Figure 4.3.8 represented that, more or less higher number of adult fruit flies had been captured in poison bait trap than pheromone trap throughout the cropping season of bitter gourd. From this study it was observed that, the average number of adult fruit flies captured in pheromone traps ranged from 6.67 to 19.00 fruit flies/trap, whereas the average number of adult fruit flies captured in poison bait trap ranged from 7.00 to 50.00 fruit flies/trap. Considering the overall average fruit fly captured, the number of adult fruit flies captured was much higher (50.00 fruit flies/trap) in poison bait trap than that of pheromone trap (19.00 fruit flies/trap).

4.3.14. Reasons for variations of number of fruit fly captured in poison bait trap

In case of poison bait trap, the less number (25.83) of adult fruit fly captured per trap was observed at 60 DAT and from 68 DAT to onward data recording time, but higher number of fruit fly captured at 64 DAT. Now the question arises what were the reasons for lower number of adult fruit flies captured in those data recording times as compared with other data recording times.

In depth analysis was done to find out the above mentioned reasons for variations of adult fruit fly capture in poison bait traps. From the data represent in the Table 4.3.1, 4.3.2 and 4.3.3, it was revealed that at early fruit and late fruit stage of the cropping season, the lower number of fruits of bitter gourd was produced. Thus the incidence of less number of adult fruit flies might be occurred to attack fruit flies than that of mid fruiting stage of bitter gourd. That's why the less number of fruit flies might be captured in the poison bait.

On the other hand, the temperature variation throughout the data recording time was ranged from 29.5 to 35.0^{o}C, of which the highest temperature (35.0^{o}C) was recorded at 60 DAT and lowest temperature (29.5^{o}C) was recorded at 64 DAT (Figure 4.3.9). This highest temperature might be responsible for drying up of the materials kept in poison bait traps. That's why the less number of adult fruit flies was captured in poison bait trap at 60 DAT, but this highest temperature did not affect the number of fruit fly captured in pheromone trap. On the other hand, the lower temperature at 64 DAT might be responsible for higher number of adult fruit flies per trap due to presence of more suitable temperature for fruit flies.

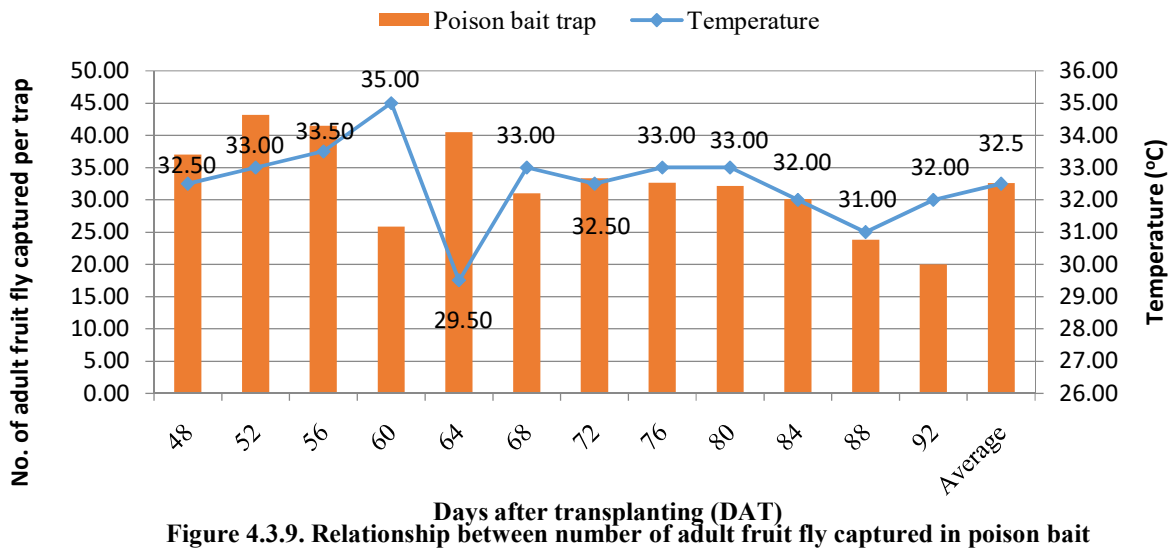

Figure 4.3.9. Relationship between number of adult fruit fly captured in poison bait trap and temperature

From the above findings it was revealed that poison bait trap was more effective than pheromone trap in terms of capturing adult fruit fly throughout the cropping season, where in case of poison bait trap the average number of adult fruit flies captured per trap was 32.6 and in case of pheromone trap this number was 17.9 fruit flies per trap. The higher temperature (35°C) negatively affected the capturing of adult fruit fly for poison bait trap because of drying up of bait materials, but not affected on the adult capturing capacity of pheromone trap.

4.3.15. Economic analysis of different management practices applied against cucurbit fruit fly infesting bitter gourd

Economic analysis of different management practices applied against cucurbit fruit fly infestation on bitter gourd presented in Table 4.3.14. The untreated control (T_8) did not incur any pest management cost. The labor costs were involved in T_1, T_2, T_3, T_4, T_5, T_6 and T_7 for applying treatments in the experimental plots (Appendix IV). From the economic analysis, the highest benefit cost ratio (BCR) (2.47) was calculated in T_2 (poison bait trap), where the total adjusted net return was counted as benefit. This was followed by T_1 (pheromone trap) (1.63) and 1.32 in T_3 (bait spray). The minimum BCR (0.30) was calculated in T_4 (spinosad spray).

Table 4.3.14. Economic analysis of different management practices applied against cucurbit fruit fly in bitter gourd during Kharif I, 2016 at Dhaka

Treatments	Cost of Management (Tk.)	Yield (kg/ha)	Gross return (Tk.)	Net Return (Tk.)	Adjusted net return (Tk.)	BCR
T_1	214450.00	13400	536000	532604	349404	1.63
T_2	208775.00	17870	714800	711453.2	528253.2	2.47
T_3	218525.00	11910	476400	472311	289111	1.32
T_4	219750.00	6320	252800	249689	66489	0.30
T_5	218100.00	9740	389600	385377.78	202177.78	0.93
T_6	218150.00	7500	300000	295777.78	112577.78	0.52
T_7	218610.00	10540	421600	417511	234311	1.07
T_8	208500.00	4580	183200	183200	0	0

[T1= Setting up of pheromone trap replaced at 1 month interval, T2= Setting up of poison bait trap @ 2 gm Sevin 85 WP mixed with 100 g mashed sweet gourd and 10 ml molasses replaced at 4 days interval, T3= Bait spray @ 10 ml molasses and 1 ml Malathion mixed with 1 liter of water @ 7 days interval, T4= Spraying of spinosad @ 0.08 ml per liter of water at 7 days interval, T5= Spraying of neem oil @ 3 ml neem oil and 10 ml Trix mixed with 1 liter of water @ 7 days interval, T6= Spraying of neem seed kernel extract @ 3 ml neem seed kernel extract and 10 ml Trix mixed with 1 liter of water @ 7 days interval, T7= Spraying of Malathion 57 EC @ 1 ml mixed with 1 liter of water @ 7 days interval, T8= Untreated control; Market price of bitter gourd 1 kg = 40 Tk.]

Experiment 4: Development of integrated pest management (IPM) approach for combating cucurbit fruit fly

The present study was conducted to find out the most effective package(s) for integrated management of cucurbit fruit flies on bitter gourd as suitable management found from the previous experiment. This study was conducted in the experimental field under the Department of Entomology, SAU, Dhaka during the period from February, 2018 to June, 2018. The findings of the study had been interpreted and discussed in the following sub-headings:

4.4.1. Number of fruit fly captured in different traps

The significant variation was observed among different IPM packages used in this study in terms of number of cucurbit fruit flies captured by different traps used in different IPM packages. In case of early fruiting stage, package 1 comprises with pheromone trap along with poison bait trap showed the best performance (28.67 flies/plot) to capture fruit flies, which was followed by package 2 (21.00 flies/plot), package 7 (19.33 flies/plot), package 6 (15.33 flies/plot), package 4 (14.00 flies/plot), package 3 (12.67 flies/plot) and package 9 (11.67 flies/plot). On the other hand, the lowest cucurbit fruit flies was captured in package 5 (9.33 flies/plot) comprises with pheromone trap along with cultural practices. Here, package 8 (bait spray along with spraying neem oil) and package 10 (untreated control) failed to capture any fruit flies. More or less same trend of result observed in case of mid fruiting stage and late fruiting stage.

In case of mean number of captured cucurbit fruit fly, package 1 showed the best performance (36.00 flies/plot) to capture cucurbit fruit flies, which was followed by package 2 (22.67 flies/plot), package 7 (20.22 flies/plot), package 6 (17.34 flies/plot), package 4 (15.11 flies/plot), package 3 (13.34 flies/plot) and package 9 (12.22 flies/plot). On the other hand, the lowest

cucurbit fruit flies was captured in package 5 (10.22 flies/plot). Package 8 and package 10 did not capture any fruit flies.

Table 4.4.1. Number of captured cucurbit fruit flies in different IPM packages

Packages	Early fruiting stage	Mid fruiting stage	Late fruiting stage	Average
Package 1	28.67 a	40.00 a	39.33 a	36.00 a
Package 2	21.00 b	24.33 b	22.67 b	22.67 b
Package 3	12.67 cd	14.67 ef	12.67 de	13.34 ef
Package 4	14.00 c	17.00 de	14.33 d	15.11 de
Package 5	9.33 d	11.67 f	9.67 e	10.22 g
Package 6	15.33 c	19.33 cd	17.33 c	17.34 d
Package 7	19.33 b	22.67 bc	18.67 c	20.22 c
Package 8	0.00 e	0.00 g	0.00 f	0.00 h
Package 9	11.67 cd	13.33 f	11.67 de	12.22 fg
Package 10	0.00 e	0.00 g	0.00 f	0.00 h
CV (%)	17.95	12.59	11.97	9.18
LSD (0.05)	3.96	3.43	2.93	2.25

[Package 1: Pheromone Trap + Poison Bait Trap at 7 days interval as routine treatment; Package 2: Pheromone Trap + Bait Spray at 7 days interval as routine treatment; Package 3: Pheromone Trap + Spraying of Neem oil at 7 days interval as routine treatment; Package 4: Pheromone Trap + Spraying of Spinosad at 7 days interval as routine treatment; Package 5: Pheromone Trap + Cultural Practice comprised of collection and destruction of infested and fallen fruits from the field; Package 6: Poison Bait Trap + Spraying of Neem oil at 7 days interval as routine treatment; Package 7: Poison Bait Trap + Spraying of Spinosad at 7 days interval as routine treatment; Package 8: Bait Spray + Spraying of Neem oil at 7 days interval as routine treatment; Package 9: Poison Bait Trap + Cultural Practice comprised of collection and destruction of infested and fallen fruits from the field; Package 10: Untreated control]

From this above findings it was revealed that, package 1 (pheromone trap along with poison bait trap) performed as the best IPM package (36.00 flies/plot) in capturing cucurbit fruit flies from bitter gourd field. Whereas the lowest performance showed in package 5 (10.22 flies/plot) (pheromone trap along with cultural practices). As a result, the order of efficacy of different IPM packages in terms of capturing cucurbit fruit flies (number) is Package 1> Package 2> Package 7> Package 6> Package 4> Package 3> Package 9> Package 5> Package 8> Package 10.

4.4.2. Fruit infestation (number)at different fruiting stages

4.4.2.1. Early fruiting stage

The efficacy of different IPM practices on fruit infestation (number) at early fruiting stage has been shown in Table 4.4.2. Significant variations were observed among the IPM packages in

terms of cucurbit fruit fly infestation (number) on bitter gourd. The highest number of bitter gourd found in Package 1 (16.33 fruits/plot) (pheromone trap along with poison bait trap), which was statistically similar with Package 2 (15.50 fruits/plot) (pheromone trap along with bait spray), followed by Package 7 (12.33 fruits/plot), Package 6 (11.00 fruits/plot), Package 4 (9.67 fruits/plot) and Package 3 (9.33 fruits/plot). On the other hand, the lowest bitter gourd was found in Package 10 (6.00 fruits/plot) (untreated control), followed by Package 5 (7.67 fruits/plot), Package 8 (7.83 fruits/plot) and Package 9 (9.00 fruits/plot) (Table 4.4.2).

The highest number of infested bitter gourd was found in Package 10 (5.33 fruits/plot), which was statistically similar with Package 5 (5.17 fruits/plot), package 8 (5.00 fruits/plot) and Package 9 (4.83 fruits/plot). On the other hand, the lowest number of infested bitter gourd was found in Package 1 (3.67 fruits/plot), which was statistically similar with Package 2 (3.83 fruits/plot), Package 7 (3.83 fruits/plot) and Package 6 (4.17 fruits/plot), followed by Package 4 (4.50 fruits/plot) and Package 3 (4.67 fruits/plot) (Table 4.4.2).

Considering the percent fruit infestation, the lowest fruit infestation (number) was observed in Package 1 (22.44%), which was statistically similar with Package 2 (24.75%) and Package 7 (31.35%), followed by Package 6 (38.23%), Package 4 (46.67%) and Package 3 (49.81%). On the other hand, the highest fruit infestation (number) was observed in Package 10 (89.18%), followed by Package 5 (68.52%), Package 8 (63.89%) and Package 9 (53.61%) (Table 4.4.2).

Considering the reduction of fruit infestation, the highest reduction of fruit infestation (number) over control was observed (74.84%) in Package 1, followed by Package 2 (72.25%), Package 7 (64.85%), Package 6 (57.13%) and Package 4 (47.67%). Whereas the lowest reduction of fruit infestation (number) over control was observed in Package 5 (23.17%), followed by Package 8 (28.36%), Package 9 (39.89%) and Package 3 (44.15%) (Table 4.4.2).

Table 4.4.2: Effect of management practices on fruit infestation (number) at early fruiting stage

Packages	Total number of fruit plot^{-1}	Number of infested fruit plot^{-1}	% fruit infestation	% reduction over control
Package 1	16.33 a	3.67 e	22.44 f	74.84
Package 2	15.50 a	3.83 e	24.75 f	72.25
Package 3	9.33 d	4.67 bcd	49.81 c	44.15
Package 4	9.67 d	4.50 cd	46.67 cd	47.67
Package 5	7.67 e	5.17 ab	68.52 b	23.17
Package 6	11.00 c	4.17 de	38.23 de	57.13
Package 7	12.33 b	3.83 e	31.35 ef	64.85
Package 8	7.83 e	5.00 abc	63.89 b	28.36
Package 9	9.00 de	4.83 abc	53.61 c	39.89
Package 10	6.00 f	5.33 a	89.18 a	0
CV (%)	7.53	6.80	11.24	-
LSD (0.05)	1.32	0.51	9.17	-

[Package 1: Pheromone Trap + Poison Bait Trap at 7 days interval as routine treatment; Package 2: Pheromone Trap + Bait Spray at 7 days interval as routine treatment; Package 3: Pheromone Trap + Spraying of Neem oil at 7 days interval as routine treatment; Package 4: Pheromone Trap + Spraying of Spinosad at 7 days interval as routine treatment; Package 5: Pheromone Trap + Cultural Practice comprised of collection and destruction of infested and fallen fruits from the field; Package 6: Poison Bait Trap + Spraying of Neem oil at 7 days interval as routine treatment; Package 7: Poison Bait Trap + Spraying of Spinosad at 7 days interval as routine treatment; Package 8: Bait Spray + Spraying of Neem oil at 7 days interval as routine treatment; Package 9: Poison Bait Trap + Cultural Practice comprised of collection and destruction of infested and fallen fruits from the field; Package 10: Untreated control]

From this above findings it was revealed that, package 1 performed as the best IPM package (22.44%) in terms of fruit infestation (number) by cucurbit fruit flies in bitter gourd field. Whereas the lowest performance showed in package 10 (89.18%) in terms of fruit infestation (number) by cucurbit fruit flies in bitter gourd field. As a result, the order of efficacy of different IPM packages in terms of fruit infestation (number) by cucurbit fruit flies in bitter gourd field at early fruiting stage is Package 1> Package 2> Package 7> Package 6> Package 4> Package 3> Package 9> Package 8> Package 5> Package 10.

4.4.2.2. Mid fruiting stage

The efficacy of different IPM practices on fruit infestation (number) at mid fruiting stage has been shown in Table 4.4.3. Significant variations were observed among the IPM packages in terms of fruit infestation (number)caused by cucurbit fruit fly on bitter gourd. The highest

number of bitter gourd was found in Package 1 (32.00 fruits/plot) (pheromone trap along with poison bait trap), which was statistically different from other treatments, followed by Package 2 (29.67 fruits/plot), Package 7 (29.00 fruits/plot), Package 6 (28.00 fruits/plot), Package 4 (27.33 fruits/plot) and Package 3 (24.67 fruits/plot). On the other hand, the lowest number of bitter gourd was found in Package 10 (16.67 fruits/plot) (untreated control), followed by Package 5 (17.33 fruits/plot), Package 8 (22.00 fruits/plot) and Package 9 (23.33 fruits/plot) (Table 4.4.3).

The highest number of infested bitter gourd was found in Package 10 (9.83 fruits/plot), which was statistically different from other treatments, followed by Package 5 (8.83 fruits/plot), Package 8 (8.17 fruits/plot) and Package 9 (7.67 fruits/plot). On the other hand, the lowest number of infested bitter gourd was found in Package 1 (5.33 fruits/plot), which was statistically similar with Package 2 (5.67 fruits/plot), followed by Package 7 (6.17 fruits/plot), Package 6 (6.50 fruits/plot), Package 4 (6.67 fruits/plot) and Package 3 (7.17 fruits/plot) (Table 4.4.3).

Considering the percent fruit infestation (number), the lowest fruit infestation (number) was observed in Package 1 (16.66%), which was statistically similar with Package 2 (19.12%), Package 7 (21.32%) and Package 6 (23.21%), followed by Package 4 (24.38%) and Package 3 (29.06%). On the other hand, the highest fruit infestation (number) was observed in Package 10 (59.63%), followed by Package 5 (51.27%), Package 8 (37.18%) and Package 9 (32.93%) (Table 4.4.3).

Considering the reduction of fruit infestation (number), the highest reduction of fruit infestation (number) over control at mid fruiting stage was observed 72.06% in Package 1, followed by Package 2 (67.94%), Package 7 (64.25%), Package 6 (61.08%) and Package 4 (59.12%). Whereas the lowest reduction of fruit infestation (number) over control was observed in Package

5 (14.02%), followed by Package 8 (37.65%), Package 9 (44.78%) and Package 3 (51.27%) (Table 4.4.3).

Table 4.4.3: Effect of management practices on fruit infestation (number) at mid fruiting stage

Packages	Total number of fruit plot^{-1}	Number of infested fruit plot^{-1}	% fruit infestation	% reduction over control
Package 1	32.00 a	5.33 h	16.66 g	72.06
Package 2	29.67 b	5.67 h	19.12 fg	67.94
Package 3	24.67 d	7.17 e	29.06 de	51.27
Package 4	27.33 c	6.67 f	24.38 ef	59.12
Package 5	17.33 f	8.83 b	51.27 b	14.02
Package 6	28.00 bc	6.50 fg	23.21 efg	61.08
Package 7	29.00 bc	6.17 g	21.32 fg	64.25
Package 8	22.00 e	8.17 c	37.18 c	37.65
Package 9	23.33 de	7.67 d	32.93 cd	44.78
Package 10	16.67 f	9.83 a	59.63 a	0
CV (%)	4.34	3.94	13.08	-
LSD (0.05)	1.81	0.48	6.88	-

[Package 1: Pheromone Trap + Poison Bait Trap at 7 days interval as routine treatment; Package 2: Pheromone Trap + Bait Spray at 7 days interval as routine treatment; Package 3: Pheromone Trap + Spraying of Neem oil at 7 days interval as routine treatment; Package 4: Pheromone Trap + Spraying of Spinosad at 7 days interval as routine treatment; Package 5: Pheromone Trap + Cultural Practice comprised of collection and destruction of infested and fallen fruits from the field; Package 6: Poison Bait Trap + Spraying of Neem oil at 7 days interval as routine treatment; Package 7: Poison Bait Trap + Spraying of Spinosad at 7 days interval as routine treatment; Package 8: Bait Spray + Spraying of Neem oil at 7 days interval as routine treatment; Package 9: Poison Bait Trap + Cultural Practice comprised of collection and destruction of infested and fallen fruits from the field; Package 10: Untreated control]

From this above findings it was revealed that, package 1 (pheromone trap along with poison bait trap) performed as the best IPM package (16.66%) in terms of fruit infestation (number)caused by cucurbit fruit flies in bitter gourd field. Whereas the lowest performance was observed in package 10 (59.63%) (untreated control) in terms of fruit infestation (number) caused by cucurbit fruit flies in bitter gourd field. As a result, the order of efficacy of different IPM packages in terms of fruit infestation (number)caused by cucurbit fruit flies in bitter gourd field at mid fruiting stage is Package 1> Package 2> Package 7> Package 6> Package 4> Package 3> Package 9> Package 8> Package 5> Package 10.

4.4.2.3.Late fruiting stage

The efficacy of different IPM practices on fruit infestation (number) at late fruiting stage has been shown in Table 4.4.4. Significant variations were observed among the IPM packages in

terms of fruit infestation (number)caused by cucurbit fruit fly on bitter gourd. The highest number of bitter gourd was found in Package 1 (28.00 fruits/plot) (pheromone trap along with poison bait trap), which was statistically different from other treatments, followed by Package 2 (24.00 fruits/plot), Package 7 (18.67 fruits/plot), Package 6 (16.67 fruits/plot), Package 4 (16.00 fruits/plot) and Package 3 (15.33 fruits/plot). On the other hand, the lowest number of bitter gourd was found in Package 10 (9.33 fruits/plot) (untreated control) which was followed by Package 5 (10.33 fruits/plot), Package 8 (11.67 fruits/plot) and Package 9 (14.67 fruits/plot) (Table 4.4.4).

The highest number of infested bitter gourd was found in Package 10 (6.50 fruits/plot), which was statistically different from other treatments, followed by Package 5 (5.83 fruits/plot), Package 8 (5.33 fruits/plot) and Package 9 (5.17 fruits/plot). On the other hand, the lowest number of infested bitter gourd was found in Package 1 (3.83 fruits/plot), which was statistically similar with Package 2 (4.17 fruits/plot) and Package 7 (4.17 fruits/plot), followed by Package 6 (4.50 fruits/plot), Package 4 (4.67 fruits/plot) and Package 3 (4.67 fruits/plot) (Table 4.4.4).

Considering the percent fruit infestation (number), the lowest fruit infestation (number) was observed in Package 1 (13.68%), which was statistically similar with Package 2 (17.45%), followed by Package 7 (22.32%), Package 6 (27.08%), Package 4 (29.31%) and Package 3 (30.66%). On the other hand, the highest fruit infestation (number) was observed in Package 10 (70.42%), followed by Package 5 (56.67%), Package 8 (45.71%) and Package 9 (35.63%) (Table 4.4.4).

Considering the reduction of fruit infestation (number), the highest reduction of fruit infestation (number) over control at mid fruiting stage was observed (80.57%) in Package 1, followed by Package 2 (75.22%), Package 7 (68.31%), Package 6 (61.55%) and Package 4 (58.38%).

Whereas the lowest reduction of fruit infestation (number) over control was observed in Package 5 (19.53%), followed by Package 8 (35.09%), Package 9 (49.40%) and Package 3 (56.46%) (Table 4.4.4).

Table 4.4.4: Effect of management practices on fruit infestation (number) at late fruiting stage

Packages	Total number of fruit plot^{-1}	Number of infested fruit plot^{-1}	% fruit infestation	% reduction over control
Package 1	28.00 a	3.83 f	13.68 h	80.57
Package 2	24.00 b	4.17 ef	17.45 gh	75.22
Package 3	15.33 de	4.67 d	30.66 de	56.46
Package 4	16.00 de	4.67 d	29.31 def	58.38
Package 5	10.33 fg	5.83 b	56.67 b	19.53
Package 6	16.67 d	4.50 de	27.08 ef	61.55
Package 7	18.67 c	4.17 ef	22.32 fg	68.31
Package 8	11.67 f	5.33 c	45.71 c	35.09
Package 9	14.67 e	5.17 c	35.63 d	49.40
Package 10	9.33 g	6.50 a	70.42 a	0
CV (%)	6.43	4.09	12.65	-
LSD (0.05)	1.77	0.33	7.37	-

[Package 1: Pheromone Trap + Poison Bait Trap at 7 days interval as routine treatment; Package 2: Pheromone Trap + Bait Spray at 7 days interval as routine treatment; Package 3: Pheromone Trap + Spraying of Neem oil at 7 days interval as routine treatment; Package 4: Pheromone Trap + Spraying of Spinosad at 7 days interval as routine treatment; Package 5: Pheromone Trap + Cultural Practice comprised of collection and destruction of infested and fallen fruits from the field; Package 6: Poison Bait Trap + Spraying of Neem oil at 7 days interval as routine treatment; Package 7: Poison Bait Trap + Spraying of Spinosad at 7 days interval as routine treatment; Package 8: Bait Spray + Spraying of Neem oil at 7 days interval as routine treatment; Package 9: Poison Bait Trap + Cultural Practice comprised of collection and destruction of infested and fallen fruits from the field; Package 10: Untreated control]

From this above findings it was revealed that, package 1 (pheromone trap along with poison bait trap) performed as the best IPM package (13.68%) in terms of fruit infestation (number) caused by cucurbit fruit flies in bitter gourd field. Whereas the lowest performance showed in package 10 (70.42%) (untreated control) in terms of fruit infestation (number) caused by cucurbit fruit flies in bitter gourd field. As a result, the order of efficacy of different IPM packages in terms of fruit infestation (number) caused by cucurbit fruit flies in bitter gourd field at late fruiting stage is Package 1> Package 2> Package 7> Package 6> Package 4> Package 3> Package 9> Package 8> Package 5> Package 10.

4.4.3. Fruit infestation (weight)at different fruiting stages

4.4.3.1. Early fruiting stage

The efficacy of different IPM practices on fruit infestation (weight) at early fruiting stage has been shown in Table 4.4.5. Significant variations were observed among the IPM packages in terms of fruit infestation (weight)caused by cucurbit fruit fly on bitter gourd. The highest weight of bitter gourd was found in Package 1 (735.00 gm) (pheromone trap along with poison bait trap), which was statistically different from other treatments, followed by Package 2 (616.67 gm), Package 7 (566.00 gm), Package 6 (460.67 gm), Package 4 (419.67 gm) and Package 3 (360.00 gm). On the other hand, the lowest weight of bitter gourd was found in Package 10 (141.00 gm) (untreated control) which was statistically similar with Package 5 (168.67 gm), followed by Package 8 (310.00 gm) and Package 9 (325.00 gm) (Table 4.4.5).

The highest weight of infested bitter gourd was found in Package 10 (129.67 gm), which was statistically different from other treatments, followed by Package 5 (124.33 gm), Package 8 (118.67 gm) and Package 9 (113.67 gm). On the other hand, the lowest weight of infested bitter gourd was found in Package 1 (86.67 gm), which was statistically similar with Package 2 (89.33 gm), followed by Package 7 (92.67 gm), Package 6 (96.33 gm), Package 4 (101.67 gm) and Package 3 (107.00 gm) (Table 4.4.5).

Considering the percent fruit infestation (weight), the lowest fruit infestation (weight) was found in Package 1 (11.83%), which was statistically similar with Package 2 (14.79%), Package 7 (16.90%) and Package 6 (21.10%), followed by Package 4 (24.31%) and Package 3 (29.92%).

On the other hand, the highest fruit infestation (weight) was observed in Package 10 (92.46%), followed by Package 5 (74.42%), Package 8 (38.64%) and Package 9 (35.44%) (Table 4.4.5). Considering the reduction of fruit infestation (weight), the highest reduction of fruit infestation (weight) over control was observed (87.21%) in Package 1, followed by Package 2 (84.00%), Package 7 (81.72%), Package 6 (77.18%) and Package 4 (73.71%). Whereas the lowest reduction of fruit infestation (weight) over control was observed in Package 5 (19.51%), followed by Package 8 (58.21%), Package 9 (61.67%) and Package 3 (67.64%) (Table 4.4.5).

Table 4.4.5: Effect of management practices on fruit infestation (weight) at early fruiting stage

Packages	Total number of fruit plot^{-1}	Number of infested fruit plot^{-1}	% fruit infestation	% reduction over control
Package 1	735.00 a	86.67 i	11.83 f	87.21
Package 2	616.67 b	89.33 hi	14.79 ef	84.00
Package 3	360.00 de	107.00 e	29.92 cd	67.64
Package 4	419.67 cd	101.67 f	24.31 de	73.71
Package 5	168.67 f	124.33 b	74.42 b	19.51
Package 6	460.67 c	96.33 g	21.10 def	77.18
Package 7	566.00 b	92.67 gh	16.90 ef	81.72
Package 8	310.00 e	118.67 c	38.64 c	58.21
Package 9	325.00 e	113.67 d	35.44 c	61.67
Package 10	141.00 f	129.67 a	92.46 a	0
CV (%)	12.39	2.66	15.52	-
LSD (0.05)	8.49	4.70	9.32	-

[Package 1: Pheromone Trap + Poison Bait Trap at 7 days interval as routine treatment; Package 2: Pheromone Trap + Bait Spray at 7 days interval as routine treatment; Package 3: Pheromone Trap + Spraying of Neem oil at 7 days interval as routine treatment; Package 4: Pheromone Trap + Spraying of Spinosad at 7 days interval as routine treatment; Package 5: Pheromone Trap + Cultural Practice comprised of collection and destruction of infested and fallen fruits from the field; Package 6: Poison Bait Trap + Spraying of Neem oil at 7 days interval as routine treatment; Package 7: Poison Bait Trap + Spraying of Spinosad at 7 days interval as routine treatment; Package 8: Bait Spray + Spraying of Neem oil at 7 days interval as routine treatment; Package 9: Poison Bait Trap + Cultural Practice comprised of collection and destruction of infested and fallen fruits from the field; Package 10: Untreated control]

From this above findings it was revealed that, package 1 (pheromone trap along with poison bait trap) performed as the best IPM package (11.83%) in terms of fruit infestation (weight)caused by cucurbit fruit flies in bitter gourd field. Whereas the lowest performance showed in package 10 (92.46%) (untreated control) in terms of fruit infestation (weight)caused by cucurbit fruit flies in

bitter gourd field. As a result, the order of efficacy of different IPM packages in terms of fruit infestation (weight)caused by cucurbit fruit flies in bitter gourd field at early fruiting stage is Package 1> Package 2> Package 7> Package 6> Package 4> Package 3> Package 9> Package 8> Package 5> Package 10.

4.4.3.2.Mid fruiting stage

The efficacy of different IPM practices on fruit infestation (weight) at mid fruiting stage has been shown in Table 4.4.6. Significant variations were observed among the IPM packages in terms of fruit infestation (weight)caused by cucurbit fruit fly on bitter gourd. The highest weight of bitter gourd found in Package 1 (1623.33 gm) (pheromone trap along with poison bait trap), which was statistically similar with Package 2 (1530.67 gm), followed by Package 7 (1163.33 gm), Package 6 (1086.67 gm), Package 4 (942.67 gm) and Package 3 (826.33 gm). On the other hand, the lowest weight of bitter gourd was found in Package 10 (551.33 gm) (untreated control) which was statistically different from other treatments, followed by Package 5 (682.00 gm), Package 8 (741.33 gm) and Package 9 (811.00 gm) (Table 4.4.6.).

The highest weight of infested bitter gourd was found in Package 10 (475.67 gm), which was statistically different from other treatments, followed by Package 5 (413.67 gm), Package 8 (380.33 gm) and Package 9 (372.33 gm). On the other hand, the lowest weight of infested bitter gourd was found in Package 1 (271.67 gm), which was statistically similar with Package 2 (309.67 gm), followed by Package 7 (326.33 gm), Package 6 (339.33 gm), Package 4 (350.00 gm) and Package 3 (361.00 gm) (Table 4.4.6.).

Considering the percent fruit infestation (weight), the lowest weight of infested bitter gourd was found in Package 1 (17.37%), which was statistically similar with Package 2 (20.30%), followed by Package 7 (28.05%), Package 6 (31.23%), Package 4 (37.39%) and Package 3 (43.75%). On

the other hand, the highest fruit infestation (weight) was observed in Package 10 (86.48%), followed by Package 5 (60.56%), Package 8 (51.36%) and Package 9 (46.05%) (Table 4.4.6.). Considering the reduction of fruit infestation (weight), the highest reduction of fruit infestation (weight) over control was observed (79.91%) in Package 1, followed by Package 2 (76.53%), Package 7 (67.57%), Package 6 (63.89%) and Package 4 (56.77%). Whereas the lowest reduction of fruit infestation (weight) over control was observed in Package 5 (29.97%), followed by Package 8 (40.61%), Package 9 (46.75%) and Package 3 (49.41%) (Table 4.4.6.).

Table 4.4.6. Effect of management practices on fruit infestation (weight) at mid fruiting stage

Packages	**Total number of fruit plot^{-1}**	**Number of infested fruit plot^{-1}**	**% fruit infestation**	**% reduction over control**
Package 1	1623.33 a	281.67 f	17.37 g	79.91
Package 2	1530.67 a	309.67 ef	20.30 g	76.53
Package 3	826.33 d	361.00 cd	43.75 d	49.41
Package 4	942.67 c	350.00 cde	37.39 e	56.77
Package 5	682.00 e	413.67 b	60.56 b	29.97
Package 6	1086.67 b	339.33 cde	31.23 f	63.89
Package 7	1163.33 b	326.33 de	28.05 f	67.57
Package 8	741.33 de	380.33 bc	51.36 c	40.61
Package 9	811.00 d	372.33 bc	46.05 d	46.75
Package 10	551.33 f	475.67 a	86.48 a	0
CV (%)	6.55	6.66	5.28	-
LSD (0.05)	1.09	4.02	3.72	-

[Package 1: Pheromone Trap + Poison Bait Trap at 7 days interval as routine treatment; Package 2: Pheromone Trap + Bait Spray at 7 days interval as routine treatment; Package 3: Pheromone Trap + Spraying of Neem oil at 7 days interval as routine treatment; Package 4: Pheromone Trap + Spraying of Spinosad at 7 days interval as routine treatment; Package 5: Pheromone Trap + Cultural Practice comprised of collection and destruction of infested and fallen fruits from the field; Package 6: Poison Bait Trap + Spraying of Neem oil at 7 days interval as routine treatment; Package 7: Poison Bait Trap + Spraying of Spinosad at 7 days interval as routine treatment; Package 8: Bait Spray + Spraying of Neem oil at 7 days interval as routine treatment; Package 9: Poison Bait Trap + Cultural Practice comprised of collection and destruction of infested and fallen fruits from the field; Package 10: Untreated control]

From this above findings it was revealed that, package 1 (pheromone trap along with poison bait trap) performed as the best IPM package (17.37%) in terms of fruit infestation (weight)caused by cucurbit fruit flies in bitter gourd field. Whereas the lowest performance showed in package 10 (86.48%) (untreated control) in terms of fruit infestation (weight) caused by cucurbit fruit flies in

bitter gourd field. As a result, the order of efficacy of different IPM packages in terms of fruit infestation (weight) by cucurbit fruit flies in bitter gourd field at mid fruiting stage is Package 1>Package 2> Package 7> Package 6> Package 4> Package 3> Package 9> Package 8> Package 5> Package 10.

4.4.3.3.Late fruiting stage

The efficacy of different IPM practices on fruit infestation (weight) at late fruiting stage has been shown in Table 4.4.7. Significant variations were observed among the IPM packages in terms of fruit infestation (weight) of cucurbit fruit fly on bitter gourd. The highest weight of bitter gourd found in Package 1 (927.67 gm) (pheromone trap along with poison bait trap), which was statistically different from other treatments, followed by Package 2 (863.33 gm), Package 7 (787.33 gm), Package 6 (752.67 gm), Package 4 (701.33 gm) and Package 3 (649.33 gm). On the other hand, the lowest weight of bitter gourd was found in Package 10 (474.67 gm) (untreated control), which was statistically different from other treatments, followed by Package 5 (560.67 gm), Package 8 (566.33 gm) and Package 9 (610.33 gm) (Table 4.4.7.).

The highest weight of infested bitter gourd was found in Package 10 (394.67 gm), which was statistically similar with Package 5 (389.00 gm), Package 8 (370.33 gm), Package 9 (360.67 gm), Package 3 (349.33 gm) and Package 4 (345.00 gm). On the other hand, the lowest weight of infested bitter gourd was found in Package 1 (240.00 gm), which was statistically similar with Package 2 (268.00 gm), followed by Package 7 (318.00 gm) and Package 6 (310.00 gm), (Table 4.4.7.).

Considering the percent fruit infestation (weight), the lowest fruit infestation (weight) was found in Package 1 (25.87%), which was statistically similar with Package 2 (31.08%), followed by Package 7 (40.44%), Package 6 (41.13%), Package 4 (48.91%) and Package 3 (53.75%). On the

other hand, the highest fruit infestation (weight) was observed in Package 10 (83.13%), followed by Package 5 (69.08%), Package 8 (65.16%) and Package 9 (59.37%) (Table 4.4.7.).

Considering the reduction of fruit infestation (weight), the highest reduction of fruit infestation (weight) over control was observed (68.88%) in Package 1, followed by Package 2 (62.61%), Package 7 (51.35%), Package 6 (50.52%) and Package 4 (41.16%). Whereas the lowest reduction of fruit infestation (weight) over control was observed in Package 5 (16.90%), followed by Package 8 (21.62%), Package 9 (28.58%) and Package 3 (35.34%) (Table 4.4.7.).

Table 4.4.7. Effect of management practices on fruit infestation (weight) at late fruiting stage

Packages	**Total number of fruit plot^{-1}**	**Number of infested fruit plot^{-1}**	**% fruit infestation**	**% reduction over control**
Package 1	927.67 a	240.00 e	25.87 h	68.88
Package 2	863.33 b	268.00 de	31.08 h	62.61
Package 3	649.33 ef	349.33 abc	53.75 de	35.34
Package 4	701.33 de	345.00 abc	48.91 ef	41.16
Package 5	560.67 g	389.00 a	69.08 b	16.90
Package 6	752.67 cd	310.00 cd	41.13 fg	50.52
Package 7	787.33 c	318.00 bcd	40.44 g	51.35
Package 8	566.33 g	370.33 ab	65.16 bc	21.62
Package 9	610.33 fg	360.67 abc	59.37 cd	28.58
Package 10	474.67 h	394.67 a	83.13 a	0
CV (%)	5.15	9.57	9.24	-
LSD (0.05)	1.59	2.54	7.98	-

[Package 1: Pheromone Trap + Poison Bait Trap at 7 days interval as routine treatment; Package 2: Pheromone Trap + Bait Spray at 7 days interval as routine treatment; Package 3: Pheromone Trap + Spraying of Neem oil at 7 days interval as routine treatment; Package 4: Pheromone Trap + Spraying of Spinosad at 7 days interval as routine treatment; Package 5: Pheromone Trap + Cultural Practice comprised of collection and destruction of infested and fallen fruits from the field; Package 6: Poison Bait Trap + Spraying of Neem oil at 7 days interval as routine treatment; Package 7: Poison Bait Trap + Spraying of Spinosad at 7 days interval as routine treatment; Package 8: Bait Spray + Spraying of Neem oil at 7 days interval as routine treatment; Package 9: Poison Bait Trap + Cultural Practice comprised of collection and destruction of infested and fallen fruits from the field; Package 10: Untreated control]

From this above findings it was revealed that, package 1 (pheromone trap along with poison bait trap) performed as the best IPM package (25.87%) in terms of fruit infestation (weight)caused by cucurbit fruit flies in bitter gourd field. Whereas the lowest performance showed in package 10 (83.13%) (untreated control) in terms of fruit infestation (weight)caused by cucurbit fruit flies in

bitter gourd field. As a result, the order of efficacy of different IPM packages in terms of fruit infestation (weight) caused by cucurbit fruit flies in bitter gourd field at late fruiting stage is Package 1> Package 2> Package 7> Package 6> Package 4> Package 3> Package 9> Package 8> Package 5> Package 10.

4.4.4. Percent edible portion of fruit at different fruiting stage

4.4.4.1. Early fruiting stage

The effect of management practices on the percent edible portion of infested fruit at early fruiting stage has been shown in Table 4.4.8. Significant variations were observed among the treatments in terms of percent edible portion of infested bitter gourd caused by cucurbit fruit fly. The highest percent edible portion of infested bitter gourd was recorded in Package 1 (90.75%), which was statistically different from all other treatments, followed by Package 2 (82.32%), Package 7 (79.78%), Package 6 (78.59%), Package 4 (77.56%) and Package 3 (63.30%). On the other hand, the lowest percent edible portion of infested bitter gourd was recorded in Package 10 (34.98%), which was statistically different from others, followed by Package 5 (48.89%), Package 8 (53.58%) and Package 9 (57.42%) (Table 4.4.8).

Considering the increase of percent edible portion of infested bitter gourd, the highest increase of percent edible portion of infested bitter gourd over control was observed (160.49%) in Package 1, followed by Package 2 (135.34%), Package 7 (128.07%), Package 6 (124.67%), Package 4 (121.73%) and Package 3 (80.96%). Whereas the lowest increase of percent edible portion of infested bitter gourd over control was recorded in Package 5 (39.77%), followed by Package 8 (53.17%) and Package 9 (64.15%) (Table 4.4.8).

Table 4.4.8. Effect of management practices on percent edible portion of infested bitter gourd at early fruiting stage

Packages	Weight of edible portion of infested fruit plot^{-1}	% edible portion	% reduction over control
Package 1	117.67 a	90.75 a	160.49
Package 2	102.33 b	82.32 b	135.34
Package 3	64.33 f	63.30 e	80.96
Package 4	83.00 e	77.56 d	121.73
Package 5	43.67 i	48.89 h	39.77
Package 6	89.33 d	78.59 d	124.67
Package 7	94.67 c	79.78 c	128.07
Package 8	49.67 h	53.58 g	53.17
Package 9	55.33 g	57.42 f	64.15
Package 10	30.33 j	34.98 i	0
CV (%)	3.12	0.95	-
LSD (0.05)	3.81	1.06	-

[Package 1: Pheromone Trap + Poison Bait Trap at 7 days interval as routine treatment; Package 2: Pheromone Trap + Bait Spray at 7 days interval as routine treatment; Package 3: Pheromone Trap + Spraying of Neem oil at 7 days interval as routine treatment; Package 4: Pheromone Trap + Spraying of Spinosad at 7 days interval as routine treatment; Package 5: Pheromone Trap + Cultural Practice comprised of collection and destruction of infested and fallen fruits from the field; Package 6: Poison Bait Trap + Spraying of Neem oil at 7 days interval as routine treatment; Package 7: Poison Bait Trap + Spraying of Spinosad at 7 days interval as routine treatment; Package 8: Bait Spray + Spraying of Neem oil at 7 days interval as routine treatment; Package 9: Poison Bait Trap + Cultural Practice comprised of collection and destruction of infested and fallen fruits from the field; Package 10: Untreated control]

From the above findings it was revealed that, the highest percent edible portion of infested bitter gourd (90.75%) was recorded in Package 1(using the pheromone trap along with the poison bait trap) in the field, where the highest increase of percent edible portion of infested bitter gourd over control was 160.49%. As a result, the order of efficacy in terms of increase the percent edible portion of infested bitter gourd fruit at early fruiting stage is Package 1> Package 2> Package 7> Package 6> Package 4> Package 3> Package 9> Package 8> Package 5> Package 10.

4.4.4.2. Mid fruiting stage

The effect of management practices on the percent edible portion of infested fruit at mid fruiting stage has been shown in Table 4.4.9. Significant variations were observed among the treatments in terms of percent edible portion of infested bitter gourd caused by cucurbit fruit fly. The

highest percent edible portion of infested bitter gourd was recorded in Package 1 (87.67%), which was statistically different from all other treatments, followed by Package 2 (49.08%), Package 7 (48.52%), Package 6 (47.29%), Package 4 (37.04%) and Package 3 (29.74%). On the other hand, the lowest percent edible portion of infested bitter gourd was recorded in Package 10 (15.41%), which was statistically different from others, followed by Package 5 (23.51%), Package 8 (27.06%) and Package 9 (27.76%) (Table 4.4.9).

Considering the increase of percent edible portion of infested bitter gourd, the highest increase of percent edible portion of infested bitter gourd over control was observed (468.92%) in Package 1, followed by Package 2 (218.50%), Package 7 (214.86%), Package 6 (206.88%), Package 4 (140.36%) and Package 3 (92.99%). Whereas the lowest increase of percent edible portion of infested bitter gourd over control was recorded in Package 5 (52.56%), followed by Package 8 (75.60%) and Package 9 (80.14%) (Table 4.4.9).

Table 4.4.9. Effect of management practices on percent edible portion of infested bitter gourd at mid fruiting stage

Packages	**Weight of edible portion of infested fruit plot^{-1}**	**% edible portion**	**% reduction over control**
Package 1	416.33 a	87.67 a	468.92
Package 2	186.33 b	49.08 b	218.50
Package 3	104.00 cd	29.74 d	92.99
Package 4	133.33 c	37.04 c	140.36
Package 5	72.67 de	23.51 e	52.56
Package 6	175.67 b	47.29 b	206.88
Package 7	200.33 b	48.52 b	214.86
Package 8	88.33 d	27.06 de	75.60
Package 9	94.00 d	27.76 de	80.14
Package 10	43.33 e	15.41 f	0
CV (%)	12.93	7.20	-
LSD (0.05)	3.27	4.73	-

[Package 1: Pheromone Trap + Poison Bait Trap at 7 days interval as routine treatment; Package 2: Pheromone Trap + Bait Spray at 7 days interval as routine treatment; Package 3: Pheromone Trap + Spraying of Neem oil at 7 days interval as routine treatment; Package 4: Pheromone Trap + Spraying of Spinosad at 7 days interval as routine treatment; Package 5: Pheromone Trap + Cultural Practice comprised of collection and destruction of infested and fallen fruits from the field; Package 6: Poison Bait Trap + Spraying of Neem oil at 7 days interval as routine treatment; Package 7: Poison Bait Trap + Spraying of Spinosad at 7 days interval as routine treatment; Package 8: Bait Spray + Spraying of Neem oil at 7 days interval as routine treatment; Package 9: Poison Bait Trap + Cultural

Practice comprised of collection and destruction of infested and fallen fruits from the field; Package 10: Untreated control]

From the above findings it was revealed that, the highest percent edible portion of infested bitter gourd (87.67%) was recorded in Package 1(using the pheromone trap along with the poison bait trap) in the field, where the highest increase of percent edible portion of infested bitter gourd over control was 468.92%. As a result, the order of efficacy in terms of increase the percent edible portion of infested bitter gourd fruit at mid fruiting stage is Package 1> Package 2> Package 7> Package 6> Package 4> Package 3> Package 9> Package 8> Package 5> Package 10.

4.4.4.3. Late fruiting stage

The effect of management practices on the percent edible portion of infested fruit at late fruiting stage has been shown in Table 4.4.10. Significant variations were observed among the treatments in terms of percent edible portion ofinfested bitter gourd. The highest percent edible portion of infested bitter gourd was recorded in Package 1 (92.91%), which was statistically different from all other treatments, followed by Package 2 (44.69%), Package 7 (43.51%), Package 6 (42.24%), Package 4 (35.00%) and Package 3 (28.11%). On the other hand, the lowest percent edible portion of infested bitter gourd was recorded in Package 10 (14.32%), which was statistically different from others, followed by Package 5 (21.50%), Package 8 (23.53%) and Package 9 (25.56%) (Table 4.4.10).

Considering the increase of percent edible portion of infested bitter gourd, the highest increase of percent edible portion of infested bitter gourd over control was observed (548.81%) in Package 1, followed by Package 2 (212.08%), Package 7 (203.84%), Package 6 (194.97%), Package 4 (144.41%) and Package 3 (96.30%). Whereas the lowest increase of percent edible portion of infested bitter gourd over control was recorded in Package 5 (50.14%), followed by Package 8 (64.32%) and Package 9 (78.49%) (Table 4.4.10).

Table 4.4.10. Effect of management practices on percent edible portion of infested bitter gourd at late fruiting stage

Packages	Weight of edible portion of infested fruit plot^{-1}	% edible portion	% reduction over control
Package 1	366.00 a	92.91 a	548.81
Package 2	165.33 b	44.69 b	212.08
Package 3	96.67 cd	28.11 e	96.30
Package 4	122.00 c	35.00 d	144.41
Package 5	57.67 ef	21.50 h	50.14
Package 6	152.33 b	42.24 c	194.97
Package 7	168.67 b	43.51 bc	203.84
Package 8	74.67 de	23.53 g	64.32
Package 9	79.33 de	25.56 f	78.49
Package 10	34.33 f	14.32 i	0
CV (%)	13.73	2.24	-
LSD (0.05)	3.02	1.39	-

[Package 1: Pheromone Trap + Poison Bait Trap at 7 days interval as routine treatment; Package 2: Pheromone Trap + Bait Spray at 7 days interval as routine treatment; Package 3: Pheromone Trap + Spraying of Neem oil at 7 days interval as routine treatment; Package 4: Pheromone Trap + Spraying of Spinosad at 7 days interval as routine treatment; Package 5: Pheromone Trap + Cultural Practice comprised of collection and destruction of infested and fallen fruits from the field; Package 6: Poison Bait Trap + Spraying of Neem oil at 7 days interval as routine treatment; Package 7: Poison Bait Trap + Spraying of Spinosad at 7 days interval as routine treatment; Package 8: Bait Spray + Spraying of Neem oil at 7 days interval as routine treatment; Package 9: Poison Bait Trap + Cultural Practice comprised of collection and destruction of infested and fallen fruits from the field; Package 10: Untreated control]

From the above findings it was revealed that, the highest percent edible portion of infested bitter gourd (92.91%) was recorded in Package 1(using the pheromone trap along with the poison bait trap) in the field, where the highest increase of percent edible portion of infested bitter gourd over control was 548.81%. As a result, the order of efficacy in terms of increase the percent edible portion of infested bitter gourd fruit at late fruiting stage is Package 1> Package 2> Package 7> Package 6> Package 4> Package 3> Package 9> Package 8> Package 5> Package 10.

4.4.5. Length and girth of single healthy fruit at different fruiting stages

4.4.5.1. Early fruiting stage

Length of single healthy fruit: The effect of management practices on length of healthy fruit of bitter gourd at early fruiting stage has been shown in Table 4.4.11. Significant variations were

observed among the treatments in terms of length of healthy fruits. The highest length (21.61 cm) of bitter gourd was recorded in Package 1, that is statistically similar with Package 2 (20.58 cm), followed by Package 7 (20.10 cm), Package 6 (19.61 cm), Package 4 (19.00 cm) and Package 3 (18.67 cm). On the other hand the lowest length of healthy bitter gourd was recorded in Package 10 (15.56 cm), followed by Package 5 (16.83 cm), Package 8 (18.26 cm) and Package 9 (18.51 cm) (Table 4.4.11).

Considering the increase of fruit length, the maximum increase of bitter gourd length over control (38.88%) was observed in Package 1, which was followed by Package 2 (32.26%), Package 7 (29.18%) and Package 6 (26.03%). Whereas the minimum increase of number of fruits per plot over control was observed in package 5 (8.16%), followed by Package 8 (17.35%), Package 9 (18.96%), Package 3 (19.99%) and Package 4 (22.11%) (Table 4.4.11).

Girth of single healthy fruit: The effect of management practices on girth of healthy fruit of bitter gourd at early fruiting stage has been shown in Table 4.4.11. Significant variations were observed among the treatments in terms of girth of healthy fruits. The highest girth (12.78 cm) of bitter gourd was recorded in Package 1, which is statistically different from other treatments, followed by Package 2 (12.11 cm), Package 7 (11.92 cm), Package 6 (11.75 cm), Package 4 (11.35cm) and Package 3 (10.85 cm). On the other hand, the lowest girth of healthy bitter gourd was recorded in Package 10 (8.91 cm), which is statistically different from other treatments, followed by Package 5 (9.65 cm), Package 8 (10.13 cm) and Package 9 (10.48 cm) (Table 4.4.11).

Considering the increase of fruit girth, the maximum increase of fruit girth over control (43.43%) was recorded in Package 1, which was followed by Package 2 (35.92%), Package 7 (33.78%), Package 6 (31.87%), Package 4 (27.38%) and Package 3 (21.77%). Whereas the minimum

increase of number of fruits per plot over control was observed in Package 5 (8.31%), followed by Package 8 (13.69%) and Package 9 (17.62%) (Table 4.4.11).

Table 4.4.11. Effect of management practices on length and girth of healthy bitter gourd at early fruiting stage

Packages	Length (cm)	% increase over control	Girth (cm)	% increase over control
Package 1	21.61 a	38.88	12.78 a	43.43
Package 2	20.58 ab	32.26	12.11 b	35.92
Package 3	18.67 de	19.99	10.85 de	21.77
Package 4	19.00 cde	22.11	11.35 cd	27.38
Package 5	16.83 f	8.16	9.65 g	8.31
Package 6	19.61 bcd	26.03	11.75 bc	31.87
Package 7	20.10 bc	29.18	11.92 bc	33.78
Package 8	18.26 e	17.35	10.13 fg	13.69
Package 9	18.51 de	18.96	10.48 ef	17.62
Package 10	15.56 g	0	8.91 h	0
CV (%)	3.94	-	3.36	-
LSD (0.05)	1.24	-	0.62	-

[Package 1: Pheromone Trap + Poison Bait Trap at 7 days interval as routine treatment; Package 2: Pheromone Trap + Bait Spray at 7 days interval as routine treatment; Package 3: Pheromone Trap + Spraying of Neem oil at 7 days interval as routine treatment; Package 4: Pheromone Trap + Spraying of Spinosad at 7 days interval as routine treatment; Package 5: Pheromone Trap + Cultural Practice comprised of collection and destruction of infested and fallen fruits from the field; Package 6: Poison Bait Trap + Spraying of Neem oil at 7 days interval as routine treatment; Package 7: Poison Bait Trap + Spraying of Spinosad at 7 days interval as routine treatment; Package 8: Bait Spray + Spraying of Neem oil at 7 days interval as routine treatment; Package 9: Poison Bait Trap + Cultural Practice comprised of collection and destruction of infested and fallen fruits from the field; Package 10: Untreated control]

From the above findings it was revealed that, the highest healthy bitter gourd length and girth (21.61 cm and 12.78 cm, respectively) were recorded in Package 1 using the pheromone trap along with the poison bait trap in the field, where the maximum increase of fruit length and girth over control were 38.88% and 43.43%, respectively. As a result, the order of efficacy in increasing the girth of healthy bitter gourd at early fruiting stage is Package 1> Package 2> Package 7> Package 6> Package 4> Package 3> Package 9> Package 8> Package 5> Package 10.

4.4.5.2.Mid fruiting stage

Length of single healthy fruit: The effect of management practices on length of healthy fruit of bitter gourd at mid fruiting stage has been shown in Table 4.4.12. Significant variations were observed among the treatments in terms of length of healthy fruits. The highest length (23.22 cm) of bitter gourd was recorded in Package 1, which is statistically different from other treatments, followed by Package 2 (21.93 cm), Package 7 (21.30 cm), Package 6 (20.93 cm), Package 4 (20.60 cm) and Package 3 (20.38 cm). On the other hand the lowest length of healthy bitter gourd was recorded in Package 10 (15.92 cm), followed by Package 5 (17.62 cm), Package 8 (19.49 cm) and Package 9 (19.69 cm) (Table 4.4.12).

Considering the increase of fruit length, the maximum increase of bitter gourd length over control (45.85%) was observed in Package 1, followed by Package 2 (37.75%), Package 7 (33.79%) and Package 6 (31.47%). Whereas the minimum increase of number of fruits per plot over control was observed in package 5 (10.68%), followed by Package 8 (22.43%), Package 9 (23.68%), Package 3 (28.02%) and Package 4 (29.40%) (Table 4.4.12).

Girth of single healthy fruit: The effect of management practices on girth of healthy fruit of bitter gourd at mid fruiting stage has been shown in Table 4.4.12. Significant variations were observed among the treatments in terms of girth of healthy fruits. The highest girth (14.05 cm) of bitter gourd was recorded in Package 1, which is statistically different from other treatments, followed by Package 2 (13.27 cm), Package 7 (12.69 cm), Package 6 (12.43 cm), Package 4 (12.22cm) and Package 3 (11.89 cm). On the other hand, the lowest girth of healthy bitter gourd was recorded in Package 10 (9.96 cm), which is statistically different from other treatments, followed by Package 5 (10.41 cm), Package 8 (11.04 cm) and Package 9 (11.38 cm) (Table 4.4.12).

Considering the increase of fruit girth, the maximum increase of fruit girth over control (41.06%) was recorded in Package 1, followed by Package 2 (33.23%), Package 7 (27.41%), Package 6 (24.80%), Package 4 (22.69%) and Package 3 (19.38%). Whereas the minimum increase of number of fruits per plot over control was observed in Package 5 (4.52%), followed by Package 8 (10.84%) and Package 9 (14.26%) (Table 4.4.12).

Table 4.4.12. Effect of management practices on length and girth of healthy bitter gourd at mid fruiting stage

Packages	Length (cm)	% increase over control	Girth (cm)	% increase over control
Package 1	23.22 a	45.85	14.05 a	41.06
Package 2	21.93 b	37.75	13.27 b	33.23
Package 3	20.38 cd	28.02	11.89 e	19.38
Package 4	20.60 cd	29.40	12.22 de	22.69
Package 5	17.62 e	10.68	10.41 g	4.52
Package 6	20.93 bc	31.47	12.43 cd	24.80
Package 7	21.30 bc	33.79	12.69 c	27.41
Package 8	19.49 d	22.43	11.04 f	10.84
Package 9	19.69 d	23.68	11.38 f	14.26
Package 10	15.92 f	0	9.96 h	0
CV (%)	3.47	-	1.99	-
LSD (0.05)	1.17	-	0.40	-

[Package 1: Pheromone Trap + Poison Bait Trap at 7 days interval as routine treatment; Package 2: Pheromone Trap + Bait Spray at 7 days interval as routine treatment; Package 3: Pheromone Trap + Spraying of Neem oil at 7 days interval as routine treatment; Package 4: Pheromone Trap + Spraying of Spinosad at 7 days interval as routine treatment; Package 5: Pheromone Trap + Cultural Practice comprised of collection and destruction of infested and fallen fruits from the field; Package 6: Poison Bait Trap + Spraying of Neem oil at 7 days interval as routine treatment; Package 7: Poison Bait Trap + Spraying of Spinosad at 7 days interval as routine treatment; Package 8: Bait Spray + Spraying of Neem oil at 7 days interval as routine treatment; Package 9: Poison Bait Trap + Cultural Practice comprised of collection and destruction of infested and fallen fruits from the field; Package 10: Untreated control]

From the above findings it was revealed that, the highest healthy bitter gourd length and girth (23.22 cm and 14.05 cm, respectively) were recorded in Package 1 in the field, where the maximum increase of fruit length and girth over control were45.85% and 41.06%, respectively. As a result, the order of efficacy in increasing the girth of healthy bitter gourd at mid fruiting

stage is Package 1> Package 2> Package 7> Package 6> Package 4> Package 3> Package 9> Package 8> Package 5> Package 10.

4.4.5.3.Late fruiting stage

Length of single healthy fruit: The effect of management practices on length of healthy fruit of bitter gourd at late fruiting stage has been shown in Table 4.4.13. Significant variations were observed among the treatments in terms of length of healthy fruits. The highest length (22.75 cm) of bitter gourd was recorded in Package 1, which is statistically different from other treatments, followed by Package 2 (21.58 cm), Package 7 (21.14 cm), Package 6 (20.74 cm), Package 4 (20.36 cm) and Package 3 (20.08 cm). On the other hand the lowest length of healthy bitter gourd was recorded in Package 10 (15.67 cm), followed by Package 5 (17.32 cm), Package 8 (19.07 cm) and Package 9 (19.37 cm) (Table 4.4.13).

Considering the increase of fruit length, the maximum increase of bitter gourd length over control (45.18%) was observed in Package 1, followed by Package 2 (37.72%), Package 7 (34.91%) and Package 6 (33.35%). Whereas the minimum increase of number of fruits per plot over control was observed in package 5 (10.53%), followed by Package 8 (21.70%), Package 9 (23.61%), Package 3 (28.14%) and Package 4 (29.93%) (Table 4.4.13).

Girth of single healthy fruit: The effect of management practices on girth of healthy fruit of bitter gourd at late fruiting stage has been shown in Table 4.4.13. Significant variations were observed among the treatments in terms of girth of healthy fruits. The highest girth (13.24 cm) of bitter gourd was recorded in Package 1, which is statistically similar with Package 2 (12.83 cm), followed by Package 7 (12.48 cm), Package 6 (12.14 cm), Package 4 (11.92cm) and Package 3 (11.51 cm). On the other hand, the lowest girth of healthy bitter gourd was recorded in Package

10 (9.42 cm), which is statistically different from other treatments, followed by Package 5 (10.18 cm), Package 8 (10.69 cm) and Package 9 (11.05 cm) (Table 4.4.13).

Considering the increase of fruit girth, the maximum increase of fruit girth over control (40.55%) was recorded in Package 1, followed by Package 2 (36.20%), Package 7 (32.48%), Package 6 (28.88%), Package 4 (26.54%) and Package 3 (22.19%). Whereas the minimum increase of number of fruits per plot over control was observed in Package 5 (8.07%), followed by Package 8 (13.48%) and Package 9 (17.30%) (Table 4.4.13).

Table 4.4.13. Effect of management practices on length and girth of healthy bitter gourd at late fruiting stage

Packages	Length (cm)	% increase over control	Girth (cm)	% increase over control
Package 1	22.75 a	45.18	13.24 a	40.55
Package 2	21.58 b	37.72	12.83 ab	36.20
Package 3	20.08 cde	28.14	11.51 e	22.19
Package 4	20.36 cd	29.93	11.92 de	26.54
Package 5	17.32 f	10.53	10.18 g	8.07
Package 6	20.74 bc	32.35	12.14 cd	28.88
Package 7	21.14 bc	34.91	12.48 bc	32.48
Package 8	19.07 e	21.70	10.69 f	13.48
Package 9	19.37 de	23.61	11.05 f	17.30
Package 10	15.67 g	0	9.42 h	0
CV (%)	3.29	-	2.15	-
LSD (0.05)	1.09	-	0.42	-

[Package 1: Pheromone Trap + Poison Bait Trap at 7 days interval as routine treatment; Package 2: Pheromone Trap + Bait Spray at 7 days interval as routine treatment; Package 3: Pheromone Trap + Spraying of Neem oil at 7 days interval as routine treatment; Package 4: Pheromone Trap + Spraying of Spinosad at 7 days interval as routine treatment; Package 5: Pheromone Trap + Cultural Practice comprised of collection and destruction of infested and fallen fruits from the field; Package 6: Poison Bait Trap + Spraying of Neem oil at 7 days interval as routine treatment; Package 7: Poison Bait Trap + Spraying of Spinosad at 7 days interval as routine treatment; Package 8: Bait Spray + Spraying of Neem oil at 7 days interval as routine treatment; Package 9: Poison Bait Trap + Cultural Practice comprised of collection and destruction of infested and fallen fruits from the field; Package 10: Untreated control]

From the above findings it was revealed that, the highest healthy bitter gourd length and girth (22.75 cm and 13.24 cm, respectively) were recorded in Package 1 in the field, where the maximum increase of fruit length and girth over control were45.18% and 40.55%, respectively. As a result, the order of efficacy in increasing the girth of healthy bitter gourd at late fruiting stage is Package 1> Package 2> Package 7> Package 6> Package 4> Package 3> Package 9> Package 8> Package 5> Package 10.

4.4.6. Length and girth of single infested fruit at different fruiting stages

4.4.6.1. Early fruiting stage

Length of single infested fruit: The effect of management practices on length of infested fruit of bitter gourd at early fruiting stage has been shown in Table 4.4.14. Significant variations were observed among the treatments in terms of length of infested fruits. The highest length (18.93

cm) of bitter gourd was recorded in Package 1, that is statistically similar with package 2 (17.83 cm) and Package 7 (17.74 cm), followed by Package 6 (17.18 cm), Package 4 (16.90 cm) and Package 3 (16.55 cm). On the other hand the lowest length of infested bitter gourd was recorded in Package 10 (12.88 cm), that is statistically similar with Package 5 (13.67 cm), followed by Package 8 (15.02 cm) and Package 9 (15.50 cm) (Table 4.4.14).

Considering the increase of fruit length, the maximum increase of bitter gourd length over control (46.97%) was observed in Package 1, followed by Package 2 (38.43%), Package 7 (37.73%) and Package 6 (33.39%). Whereas the minimum increase of bitter gourd length over control was observed in package 5 (6.13%), followed by Package 8 (16.61%), Package 9 (20.34%), Package 3 (28.49%) and Package 4 (31.21%) (Table 4.4.14).

Girth of single infested fruit: The effect of management practices on girth of infested fruit of bitter gourd at early fruiting stage has been shown in Table 4.4.14. Significant variations were observed among the treatments in terms of girth of infested fruits. The highest girth (9.88 cm) of bitter gourd was recorded in Package 1, which is statistically different from other treatments, followed by Package 2 (9.33 cm), Package 7 (8.99 cm), Package 6 (8.80 cm), Package 4 (8.57cm) and Package 3 (8.20 cm). On the other hand, the lowest girth of infested bitter gourd was recorded in Package 10 (6.76 cm), which is statistically different from other treatments, followed by Package 5 (7.12 cm), Package 8 (7.41 cm) and Package 9 (7.70 cm) (Table 4.4.14).

Considering the increase of fruit girth, the maximum increase of fruit girth over control (46.15%) was recorded in Package 1, followed by Package 2 (38.02%), Package 7 (32.99%), Package 6 (30.18%), Package 4 (26.78%) and Package 3 (21.30%). Whereas the minimum increase of fruit girth over control was observed in Package 5 (5.33%), followed by Package 8 (9.62%) and Package 9 (13.91%) (Table 4.4.14).

Table 4.4.14. Effect of management practices on length and grith of infested bitter gourd at early fruiting stage

Packages	Length (cm)	% increase over control	Girth (cm)	% increase over control
Package 1	18.93 a	46.97	9.88 a	46.15
Package 2	17.83 ab	38.43	9.33 b	38.02
Package 3	16.55 bcd	28.49	8.20 d	21.30
Package 4	16.90 bc	31.21	8.57 cd	26.78
Package 5	13.67 ef	6.13	7.12 fg	5.33
Package 6	17.18 b	33.39	8.80 c	30.18
Package 7	17.74 ab	37.73	8.99 bc	32.99
Package 8	15.02 de	16.61	7.41 ef	9.62
Package 9	15.50 cd	20.34	7.70 e	13.91
Package 10	12.88 f	0	6.76 g	0
CV (%)	6.13	-	3.14	-
LSD (0.05)	1.66	-	0.43	-

[Package 1: Pheromone Trap + Poison Bait Trap at 7 days interval as routine treatment; Package 2: Pheromone Trap + Bait Spray at 7 days interval as routine treatment; Package 3: Pheromone Trap + Spraying of Neem oil at 7 days interval as routine treatment; Package 4: Pheromone Trap + Spraying of Spinosad at 7 days interval as routine treatment; Package 5: Pheromone Trap + Cultural Practice comprised of collection and destruction of infested and fallen fruits from the field; Package 6: Poison Bait Trap + Spraying of Neem oil at 7 days interval as routine treatment; Package 7: Poison Bait Trap + Spraying of Spinosad at 7 days interval as routine treatment; Package 8: Bait Spray + Spraying of Neem oil at 7 days interval as routine treatment; Package 9: Poison Bait Trap + Cultural Practice comprised of collection and destruction of infested and fallen fruits from the field; Package 10: Untreated control]

From the above findings it was revealed that, the highest infested bitter gourd length and girth (18.93 cm and 9.88 cm, respectively) were recorded in Package 1 in the field, where the maximum increase of fruit length and girth over control were46.97% and 46.15%, respectively. As a result, the order of efficacy in increasing the girth of infested bitter gourd at early fruiting stage is Package 1> Package 2> Package 7> Package 6> Package 4> Package 3> Package 9> Package 8> Package 5> Package 10.

4.4.6.2. Mid fruiting stage

Length of single infested fruit: The effect of management practices on length of infested fruit of bitter gourd at mid fruiting stage has been shown in Table 4.4.15. Significant variations were observed among the treatments in terms of length of infested fruits. The highest length (19.68 cm) of bitter gourd was recorded in Package 1, which is statistically similar with Package 2

(18.76 cm) and Package 7 (18.38 cm), followed by Package 6 (17.95 cm), Package 4 (17.46 cm) and Package 3 (17.10 cm). On the other hand the lowest length of infested bitter gourd was recorded in Package 10 (13.79 cm), followed by Package 5 (14.71 cm), Package 8 (15.65 cm) and Package 9 (16.25 cm) (Table 4.4.15).

Considering the increase of fruit length, the maximum increase of bitter gourd length over control (42.71%) was observed in Package 1, followed by Package 2 (36.04%), Package 7 (33.29%) and Package 6 (30.17%). Whereas the minimum increase of fruit length over control was observed in package 5 (6.67%), followed by Package 8 (13.49%), Package 9 (17.84%), Package 3 (24.00%) and Package 4 (26.61%) (Table 4.4.15).

Girth of single infested fruit: The effect of management practices on girth of infested fruit of bitter gourd at mid fruiting stage has been shown in Table 4.4.15. Significant variations were observed among the treatments in terms of girth of infested fruits. The highest girth (10.58 cm) of bitter gourd was recorded in Package 1, which is statistically different from other treatments, followed by Package 2 (10.25 cm), Package 7 (10.01 cm), Package 6 (9.85 cm), Package 4 (9.55 cm) and Package 3 (9.24 cm). On the other hand, the lowest girth of infested bitter gourd was recorded in Package 10 (8.08 cm), which is statistically different from other treatments, followed by Package 5 (8.40 cm), Package 8 (8.80 cm) and Package 9 (8.99 cm) (Table 4.4.15).

Considering the increase of fruit girth, the maximum increase of fruit girth over control (30.94%) was recorded in Package 1, followed by Package 2 (26.86%), Package 7 (23.89%), Package 6 (21.91%), Package 4 (18.19%) and Package 3 (14.36%). Whereas the minimum increase of number of fruits per plot over control was observed in Package 5 (3.96%), followed by Package 8 (8.91%) and Package 9 (11.26%) (Table 4.4.15).

Table 4.4.15. Effect of management practices on length and girth of infested bitter gourd at mid fruiting stage

Packages	Length (cm)	% increase over control	Girth (cm)	% increase over control
Package 1	19.68 a	42.71	10.58 a	30.94
Package 2	18.76 ab	36.04	10.25 b	26.86
Package 3	17.10 cde	24.00	9.24 e	14.36
Package 4	17.46 bcd	26.61	9.55 d	18.19
Package 5	14.71 fg	6.67	8.40 h	3.96
Package 6	17.95 bc	30.17	9.85 c	21.91
Package 7	18.38 abc	33.29	10.01 c	23.89
Package 8	15.65 ef	13.49	8.80 g	8.91
Package 9	16.25 de	17.84	8.99 f	11.26
Package 10	13.79 g	0	8.08 i	0
CV (%)	5.22	-	1.04	-
LSD (0.05)	1.48	-	0.17	-

[Package 1: Pheromone Trap + Poison Bait Trap at 7 days interval as routine treatment; Package 2: Pheromone Trap + Bait Spray at 7 days interval as routine treatment; Package 3: Pheromone Trap + Spraying of Neem oil at 7 days interval as routine treatment; Package 4: Pheromone Trap + Spraying of Spinosad at 7 days interval as routine treatment; Package 5: Pheromone Trap + Cultural Practice comprised of collection and destruction of infested and fallen fruits from the field; Package 6: Poison Bait Trap + Spraying of Neem oil at 7 days interval as routine treatment; Package 7: Poison Bait Trap + Spraying of Spinosad at 7 days interval as routine treatment; Package 8: Bait Spray + Spraying of Neem oil at 7 days interval as routine treatment; Package 9: Poison Bait Trap + Cultural Practice comprised of collection and destruction of infested and fallen fruits from the field; Package 10: Untreated control]

From the above findings it was revealed that, the highest infested bitter gourd length and girth (19.68 cm and 10.58 cm, respectively) were recorded in Package 1 in the field, where the maximum increase of fruit length and girth over control were42.71% and 30.94%, respectively. As a result, the order of efficacy in increasing the girth of infested bitter gourd at mid fruiting stage is Package 1> Package 2> Package 7> Package 6> Package 4> Package 3> Package 9> Package 8> Package 5> Package 10.

4.4.6.3. Late fruiting stage

Length of single infested fruit: The effect of management practices on length of infested fruit of bitter gourd at late fruiting stage has been shown in Table 4.4.16. Significant variations were observed among the treatments in terms of length of infested fruits. The highest length (19.29 cm) of bitter gourd was recorded in Package 1, which is statistically similar with Package 2

(18.44 cm) and Package 7 (18.10 cm), followed by Package 6 (17.51 cm), Package 4 (17.20 cm) and Package 3 (16.80 cm). On the other hand the lowest length of infested bitter gourd was recorded in Package 10 (13.48 cm), followed by Package 5 (14.09 cm), Package 8 (15.34 cm) and Package 9 (16.06 cm) (Table 4.4.16).

Considering the increase of fruit length, the maximum increase of bitter gourd length over control (43.10%) was observed in Package 1, followed by Package 2 (36.80%), Package 7 (34.27%) and Package 6 (29.90%). Whereas the minimum increase of fruit length over control was observed in package 5 (4.53%), followed by Package 8 (13.80%), Package 9 (19.14%), Package 3 (24.63%) and Package 4 (27.60%) (Table 4.4.16).

Girth of single infested fruit: The effect of management practices on girth of infested fruit of bitter gourd at late fruiting stage has been shown in Table 4.4.16. Significant variations were observed among the treatments in terms of girth of infested fruits. The highest girth (10.24 cm) of bitter gourd was recorded in Package 1, which is statistically different from other treatments, followed by Package 2 (9.90 cm), Package 7 (9.68 cm), Package 6 (9.43 cm), Package 4 (9.04 cm) and Package 3 (8.82 cm). On the other hand, the lowest girth of infested bitter gourd was recorded in Package 10 (7.33 cm), which is statistically different from other treatments, followed by Package 5 (7.89 cm), Package 8 (8.19 cm) and Package 9 (8.48 cm) (Table 4.4.16).

Considering the increase of fruit girth, the maximum increase of fruit girth over control (39.70%) was recorded in Package 1, followed by Package 2 (35.06%), Package 7 (32.06%), Package 6 (28.65%), Package 4 (23.33%) and Package 3 (20.33%). Whereas the minimum increase of fruit girth over control was observed in Package 5 (7.64%), followed by Package 8 (11.73%) and Package 9 (15.69%) (Table 4.4.16).

Table 4.4.16. Effect of management practices on length and girth of infested bitter gourd at late fruiting stage

Packages	Length (cm)	% increase over control	Girth (cm)	% increase over control
Package 1	19.29 a	43.10	10.24 a	39.70
Package 2	18.44 ab	36.80	9.90 b	35.06
Package 3	16.80 cde	24.63	8.82 d	20.33
Package 4	17.20 bcd	27.60	9.04 d	23.33
Package 5	14.09 fg	4.53	7.89 g	7.64
Package 6	17.51 bcd	29.90	9.43 c	28.65
Package 7	18.10 abc	34.27	9.68 bc	32.06
Package 8	15.34 ef	13.80	8.19 f	11.73
Package 9	16.06 de	19.14	8.48 e	15.69
Package 10	13.48 g	0	7.33 h	0
CV (%)	5.84	-	1.92	-
LSD (0.05)	1.62	-	0.28	-

[Package 1: Pheromone Trap + Poison Bait Trap at 7 days interval as routine treatment; Package 2: Pheromone Trap + Bait Spray at 7 days interval as routine treatment; Package 3: Pheromone Trap + Spraying of Neem oil at 7 days interval as routine treatment; Package 4: Pheromone Trap + Spraying of Spinosad at 7 days interval as routine treatment; Package 5: Pheromone Trap + Cultural Practice comprised of collection and destruction of infested and fallen fruits from the field; Package 6: Poison Bait Trap + Spraying of Neem oil at 7 days interval as routine treatment; Package 7: Poison Bait Trap + Spraying of Spinosad at 7 days interval as routine treatment; Package 8: Bait Spray + Spraying of Neem oil at 7 days interval as routine treatment; Package 9: Poison Bait Trap + Cultural Practice comprised of collection and destruction of infested and fallen fruits from the field; Package 10: Untreated control]

From the above findings it was revealed that, the highest infested bitter gourd length and girth (19.29 cm and 10.24 cm, respectively) were recorded in Package 1 in the field, where the maximum increase of fruit length and girth over control were43.10% and 39.70%, respectively. As a result, the order of efficacy in increasing the girth of infested bitter gourd at late fruiting stage is Package 1> Package 2> Package 7> Package 6> Package 4> Package 3> Package 9> Package 8> Package 5> Package 10.

4.4.7. Effect of management practices on the yield attributes of bitter gourd

4.4.7.1. Number of fruit plot^{-1}

The effect of management practices on number of fruit plot^{-1} has been shown in Table 4.4.17. Significant variations were observed among the treatments in terms of number of fruit plot^{-1} of bitter gourd. The highest number of fruit plot^{-1} (76.33 fruits/plot) was recorded in Package 1,

followed by Package 2 (69.17 fruits/plot), Package 7 (60.00 fruits/plot), Package 6 (55.67 fruits/plot), Package 4 (53.00 fruits/plot) and Package 3 (49.33 fruits/plot). On the other hand, the lowest number of fruit plot^{-1} was recorded in Package 10 (32.00 fruits/plot), which is statistically different from other treatments, followed by Package 5 (35.33 fruits/plot), Package 8 (41.50 fruits/plot) and Package 9 (47.00 fruits/plot) (Table 4.4.17).

Considering the increase of number of fruit plot^{-1}, the maximum increase of number of fruit plot^{-1} over control (138.53%) was recorded in Package 1, followed by Package 2 (116.16%), Package 7 (87.50%), Package 6 (73.97%), Package 4 (65.63%) and Package 3 (54.16%). Whereas the minimum increase of number of fruit plot^{-1} over control was observed in Package 5 (10.41%), followed by Package 8 (29.69%) and Package 9 (46.88%) (Table 4.4.17).

4.4.7.2. Single fruit weight

The effect of management practices on single fruit weight has been shown in Table 4.4.17. Significant variations were observed among the treatments in terms of single fruit weight of bitter gourd. The highest single fruit weight (50.13 g) was recorded in Package 1, followed by Package 2 (45.60 g), Package 7 (42.90 g), Package 6 (38.47 g), Package 4 (36.77 g) and Package 3 (36.26 g). On the other hand, the lowest single fruit weight was recorded in Package 10 (26.18 g), which was statistically similar with Package 5 (27.99 g), followed by Package 8 (33.15 g) and Package 9 (34.78 g) (Table 4.4.17).

Considering the increase of single fruit weight, the maximum increase of single fruit weight over control (91.48%) was recorded in Package 1, followed by Package 2 (74.18%), Package 7 (63.87%), Package 6 (46.94%), Package 4 (40.45%) and Package 3 (38.50%). Whereas the minimum increase of single fruit weight over control was observed in Package 5 (6.91%), followed by Package 8 (26.62%) and Package 9 (32.85%) (Table 4.4.17).

Table 4.4.17. Effect of management practices on the yield attributes of bitter gourd

Packages	Total no. of fruit	% increase over control	Single fruit weight (gm)	% increase over control
Package 1	76.33 a	138.53	50.13 a	91.48
Package 2	69.17 b	116.16	45.60 b	74.18
Package 3	49.33 f	54.16	36.26 cd	38.50
Package 4	53.00 e	65.63	36.77 cd	40.45
Package 5	35.33 i	10.41	27.99 f	6.91
Package 6	55.67 d	73.97	38.47 c	46.94
Package 7	60.00 c	87.50	42.90 b	63.87
Package 8	41.50 h	29.69	33.15 e	26.62
Package 9	47.00 g	46.88	34.78 de	32.85
Package 10	32.00 j	0	26.18 f	0
CV (%)	2.61	-	4.63	-
LSD (0.05)	2.26	-	2.88	-

[Package 1: Pheromone Trap + Poison Bait Trap at 7 days interval as routine treatment; Package 2: Pheromone Trap + Bait Spray at 7 days interval as routine treatment; Package 3: Pheromone Trap + Spraying of Neem oil at 7 days interval as routine treatment; Package 4: Pheromone Trap + Spraying of Spinosad at 7 days interval as routine treatment; Package 5: Pheromone Trap + Cultural Practice comprised of collection and destruction of infested and fallen fruits from the field; Package 6: Poison Bait Trap + Spraying of Neem oil at 7 days interval as routine treatment; Package 7: Poison Bait Trap + Spraying of Spinosad at 7 days interval as routine treatment; Package 8: Bait Spray + Spraying of Neem oil at 7 days interval as routine treatment; Package 9: Poison Bait Trap + Cultural Practice comprised of collection and destruction of infested and fallen fruits from the field; Package 10: Untreated control]

From the above findings it was revealed that, the highest number of fruit plot^{-1} and single fruit weight (76.33 fruits and 50.13 g, respectively) were recorded in Package 1 in the field, where the maximum increase of number of fruit plot^{-1} and single fruit weight over control were138.53% and 91.48%, respectively. As a result, the order of efficacy in increasing the single fruit weight is Package 1> Package 2> Package 7> Package 6> Package 4> Package 3> Package 9> Package 8> Package 5> Package 10.

4.4.8. Effect on yield of bitter gourd

The effect of management practices on yield of bitter gourd has been shown in Table 4.4.18. Significant variations were observed among the treatments in terms of yield of bitter gourd. The highest yield (3.83 kg/plot) was recorded in Package 1, followed by Package 2 (3.15 kg/plot), Package 7 (2.57 kg/plot), Package 6 (2.14 kg/plot), Package 4 (1.95 kg/plot) and Package 3 (1.79

kg/plot). On the other hand, the lowest yield was recorded in Package 10 (0.84 kg/plot), which is statistically similar with Package 5 (0.99 kg/plot), followed by Package 8 (1.38 kg/plot) and Package 9 (1.63 kg/plot) (Table 4.4.18).

Considering the yield of bitter gourd in ton/ha, the highest yield (12.76 ton/ha) was observed in Package 1, followed by Package 2 (10.50 ton/ha), Package 7 (8.58 ton/ha), Package 6 (7.14 ton/ha), Package 4 (6.50 ton/ha) and Package 3 (5.96 ton/ha). On the other hand, the lowest yield was observed in Package 10 (2.79 ton/ha), which is statistically similar with Package 5 (3.30 ton/ha), followed by Package 8 (4.58 ton/ha) and Package 9 (5.45 ton/ha) (Table 4.4.18).

Considering the increase of yield over control, the highest increase of yield over control (357.35%) was recorded in Package 1, followed by Package 2 (276.34%), Package 7 (207.53%), Package 6 (155.91%), Package 4 (132.98%) and Package 3 (113.62%). Whereas the lowest increase of yield over control was observed in Package 5 (18.28%), followed by Package 8 (64.16%) and Package 9 (95.34%) (Table 4.4.18).

Table 4.4.18. Effect of management practices on yield of bitter gourd

Packages	Yield per plot (Kg)	Yield (ton/ha)	% increase over control
Package 1	3.83 a	12.76 a	357.35
Package 2	3.15 b	10.50 b	276.34
Package 3	1.79 ef	5.96 ef	113.62
Package 4	1.95 de	6.50 de	132.98
Package 5	0.99 h	3.30 h	18.28
Package 6	2.14 d	7.14 d	155.91
Package 7	2.57 c	8.58 c	207.53
Package 8	1.38 g	4.58 g	64.16
Package 9	1.63 f	5.45 f	95.34
Package 10	0.84 h	2.79 h	0
CV (%)	5.76	5.69	-
LSD (0.05)	0.20	0.64	-

[Package 1: Pheromone Trap + Poison Bait Trap at 7 days interval as routine treatment; Package 2: Pheromone Trap + Bait Spray at 7 days interval as routine treatment; Package 3: Pheromone Trap + Spraying of Neem oil at 7 days interval as routine treatment; Package 4: Pheromone Trap + Spraying of Spinosad at 7 days interval as routine treatment; Package 5: Pheromone Trap + Cultural Practice comprised of collection and destruction of infested and fallen fruits from the field; Package 6: Poison Bait Trap + Spraying of Neem oil at 7 days interval as routine treatment; Package 7: Poison Bait Trap + Spraying of Spinosad at 7 days interval as routine treatment; Package 8: Bait Spray + Spraying of Neem oil at 7 days interval as routine treatment; Package 9: Poison Bait Trap + Cultural

Practice comprised of collection and destruction of infested and fallen fruits from the field; Package 10: Untreated control]

From the above findings it was revealed that, the highest yield (12.76 ton/ha) was recorded in Package 1 in the field, where the maximum increase of yield over control was 357.35%. As a result, the order of efficacy in increasing the yield of bitter gourd is Package 1> Package 2> Package 7> Package 6> Package 4> Package 3> Package 9> Package 8> Package 5> Package 10.

4.4.9. Relationship between fruit infestation and yield of bitter gourd

4.4.9.1. Early fruiting stage

Correlation study was done to establish the relationship between the percent fruit infestation by number at early fruiting stage and yield (t/ha) of bitter gourd during the management of cucurbit fruit fly. From the study it was revealed that significant correlation was observed between the fruit infestation and yield of bitter gourd (Figure 4.4.1). It was evident from the Figure 4.4.1 that the regression equation y = -0.1392x + 13.554 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.8693) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a negative relationship between fruit infestation and yield of bitter gourd, i.e., the yield decreased with the increase of the infestation of fruit by cucurbit fruit fly at early fruiting stage.

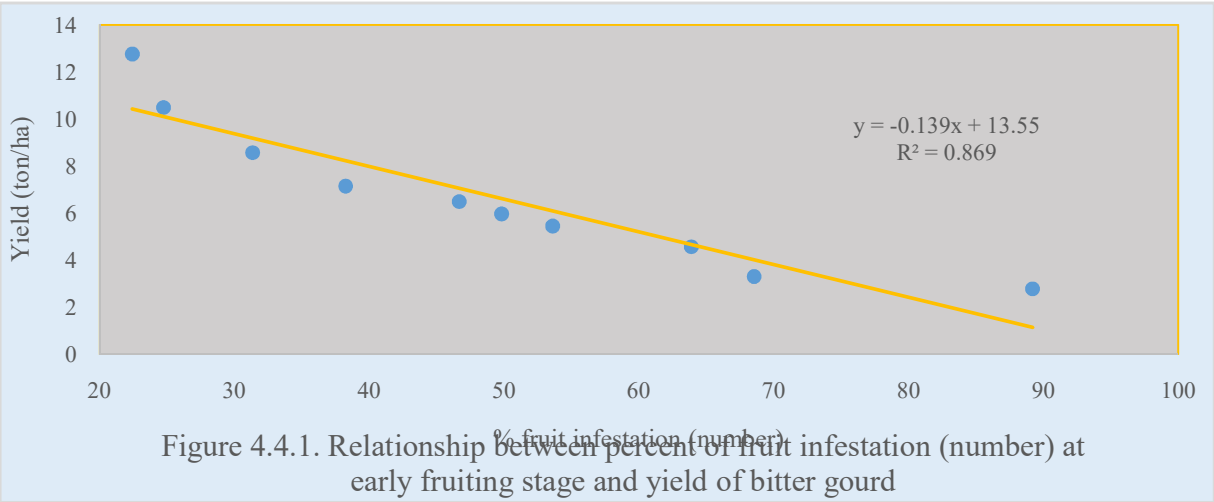

Figure 4.4.1. Relationship between percent of fruit infestation (number) at early fruiting stage and yield of bitter gourd

4.4.9.2. Mid fruiting stage

Correlation study was done to establish the relationship between the percent fruit infestation by number at mid fruiting stage and yield (t/ha) of bitter gourd during the management of cucurbit fruit fly. From the study it was revealed that significant correlation was observed between the fruit infestation and yield of bitter gourd (Figure 4.4.2). It was evident from the Figure 4.4.2 that the regression equation y = -0.1911x + 12.77 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.7516) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a negative relationship between fruit infestation and yield of bitter gourd, i.e., the yield decreased with the increase of the infestation of fruit by cucurbit fruit fly at mid fruiting stage.

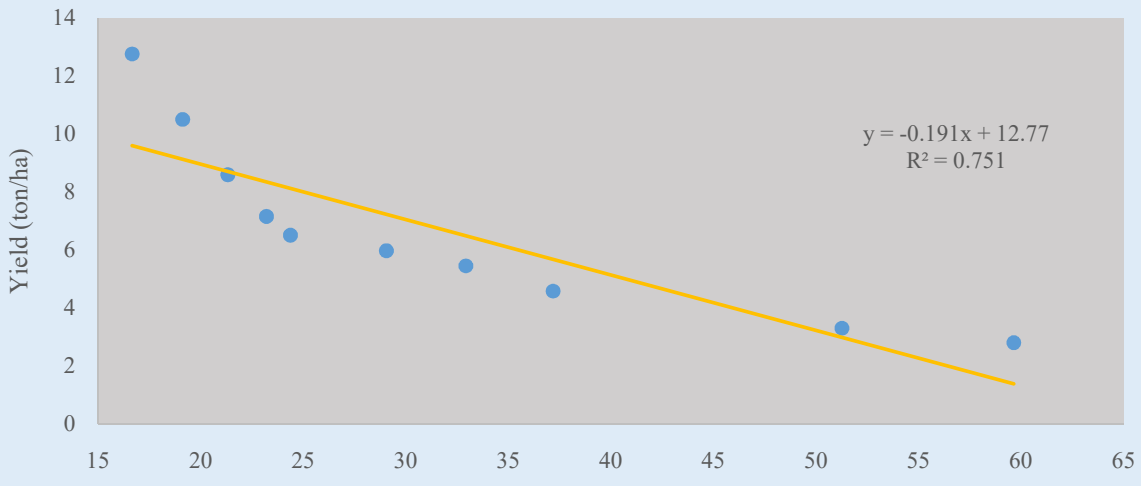

Figure 4.4.2. Relationship between percent fruit infestation (number) at mid fruiting stage and yield of bitter gourd

4.4.9.3. Late fruiting stage

Correlation study was done to establish the relationship between the percent fruit infestation by number at late fruiting stage and yield (t/ha) of bitter gourd during the management of cucurbit

fruit fly. From the study it was revealed that significant correlation was observed between the fruit infestation and yield of bitter gourd (Figure 4.4.3). It was evident from the Figure 4.4.3 that the regression equation y = -0.158x + 12.269 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.8127) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a negative relationship between fruit infestation and yield of bitter gourd, i.e., the yield decreased with the increase of

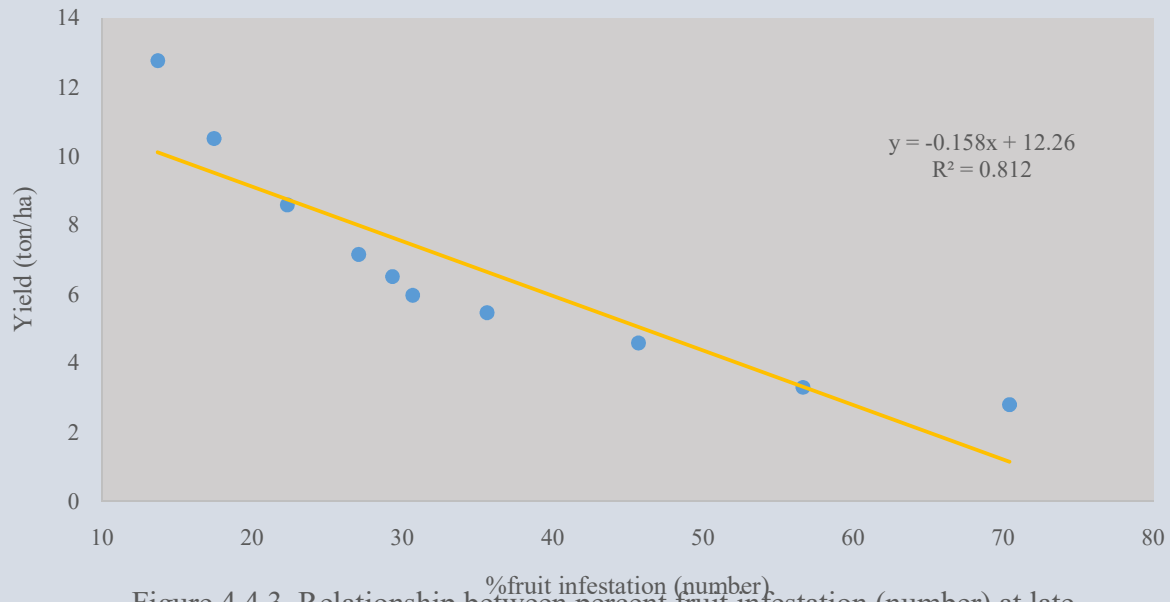

Figure 4.4.3. Relationship between percent fruit infestation (number) at late fruiting stage and yield of bitter gourd

the infestation of fruit by cucurbit fruit fly at late fruiting stage.

4.4.10. Relationship between number of fruits per plot and yield

Correlation study was done to establish the relationship between the number of fruit per plot and yield (t/ha) of bitter gourd during the management of cucurbit fruit fly. From the study it was revealed that significant correlation was observed between the number of fruit per plot and yield of bitter gourd (Figure 4.4.4). It was evident from the Figure 4.4.4 that the regression equation y = 0.221x – 4.72 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.9868)

showed that, fitted regression line had a significant regression co-efficient. From this regression analysis it was evident that there was a positive relationship between total number of fruit per plot and the yield of bitter gourd, i.e., the yield increased with the increase of the total number of

Figure 4.4.4. Relationship between total number of fruit plot^{-1} and yield of bitter gourd

fruit per plot.

4.4.11. Relationship between single fruit weight and yield

Correlation study was done to establish the relationship between the single fruit weight and yield (t/ha) of bitter gourd during the management of cucurbit fruit fly. From the study it was revealed that significant correlation was observed between the single fruit weight and yield of bitter gourd (Figure 4.4.5). It was evident from the Figure 4.4.5 that the regression equation y = 0.4155x – 8.7092 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.9797) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a positive relationship between single fruit weight and yield of bitter gourd, i.e., the yield increased with the increase of the single fruit weight.

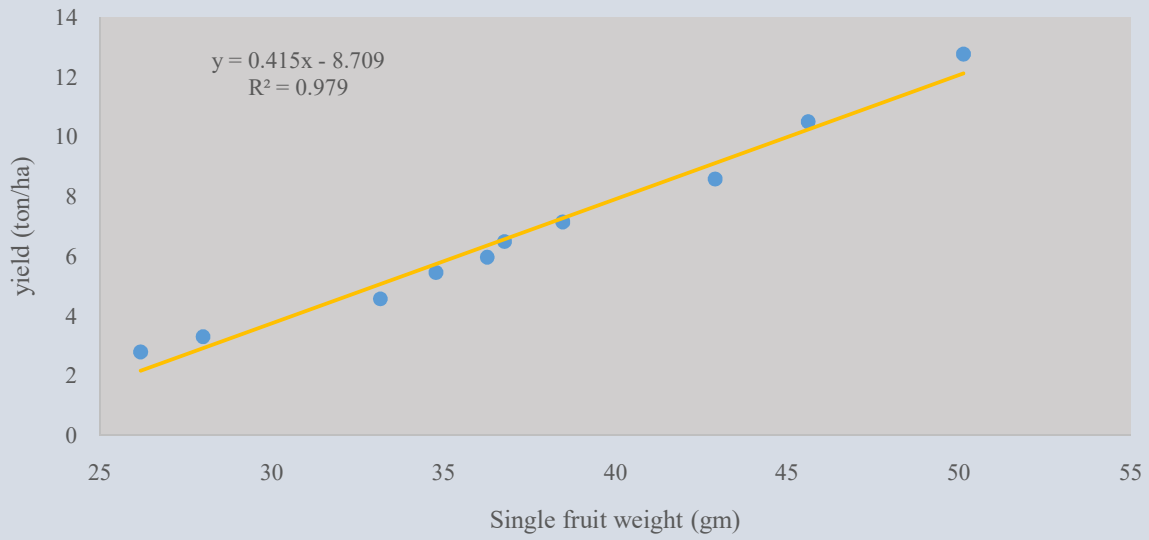

Figure 4.4.5. Relationship between single fruit weight and yield of bitter gourd

CHAPTER V

SUMMARY AND CONCLUSION

The experiments were conducted in the Entomology experimental field, Horticulture experimental field and Central Laboratory of Sher-e-Bangla Agricultural University (SAU), Sher-e-Banglanagar, Dhaka, Bangladesh, during March 2016 to August 2018 to evaluate the bio-ecology, damage assessment and management practices of cucurbit fruit fly. Based on the findings of the research, the summary and conclusion are made bellow:

SUMMARY

Cucurbit fruit fly was the major insect pest of cucurbitaceouscrops i.e. all cucurbit crops were infested by cucurbit fruit fly. The average number of cucurbit fruit fly, percent fruit infestation by number, percent fruit infestation by weight, percent edible portion of infested fruit, number of bore on infested fruit caused by cucurbit fruit fly remain low in kharif season and high in robi season. Besides this, highest average number of cucurbit fruit fly, percent fruit infestation by number, percent fruit infestation by weight, percent edible portion of infested fruit, number of bore on infested fruit caused by cucurbit fruit fly was found high in bitter gourd and low in sweet gourd.

The result showed the incubation, larval and pupal periodin room temperature and laboratory condition were 1.7 ± 0.823 days and 2.7 ± 0.823 days;4.3 ± 0.675 days and 5.5± 0.85 days; and 5.9 ± 0.738 days and 9.8 ± 1.033 days, respectively. Average adult longevity of male and female cucurbit fruit flies under room temperature and laboratory conditions were 5.9 ± 0.568 days and 13.3 ± 0.95 days; and 6.7 ± 0.675 days and 15.8 ± 1.229 days, respectively. Average total life cycle of cucurbit fruit flies for adult male and female under room temperature and laboratory conditions were 16.1 ± 1.1 days and 28.6 ± 2.171 days;and 16.9 ± 1.287 days and 31.1± 2.514

days,respectively. Ovipositional period of adult female cucurbit fruit flies under room temperature and laboratory conditions were 1.4 ± 0.516 days and 2.9 ± 0.738 days, respectively. Length and breadth of cucurbit fruit fly eggs, larvae and pupa were 1.14 ± 0.07 mm and 0.22 ± 0.01 mm; 7.9 ± 0.994 mm and 2.04 ± 0.062 mm; and 6.2 ± 1.135 mm and 2.38 ± 0.161 mm, respectively. Length and breadth of adult male and female cucurbit fruit fly were 7.4 ± 1.075 mm and 11.4 ± 0.342 mm; and 9.3 ± 0.823 mm and 15.69 ± 0.418 mm, respectively.

Considering the effect of different management practices in reducing the level of infestation by cucurbit fruit flies on bitter gourd at early fruiting stage, the lowest number of fruit infestation (6.28%) was recorded in T_2 and the highest reduction of fruit infestation over control was 76.72%. As a result, the order of efficacy of management practices in terms of fruit infestation reduction by number is $T_2>T_1>T_3>T_5>T_7>T_6>T_4>T_8$. In case of mid fruiting stage, the lowest number of fruit infestation (12.89%) was recorded in T_2 and the highest reduction of fruit infestation over control was 83.78%. As a result, the order of efficacy of management practices in terms of fruit infestation reduction by number is $T_2>T_1>T_3>T_7>T_5>T_6>T_4>T_8$. At late fruiting stage, the lowest number of fruit infestation (14.67%) was recorded in T_2 using the poison bait trap in the field and the highest reduction of fruit infestation over control was 83.20%. As a result, the order of efficacy of management practices in terms of fruit infestation reduction by number is $T_2>T_1>T_3>T_7>T_5>T_6>T_4>T_8$.

In the term of fruit infestation by weightat early fruiting stage, the lowest fruit infestation (19.30%) was recorded in T_2, and the highest reduction of fruit infestation over control was 78.73%. As a result, the order of efficacy of management practices in terms of fruit infestation reduction is $T_2>T_1>T_3>T_7>T_5>T_6>T_4>T_8$. In case of mid fruiting stage, the lowest fruit infestation (6.18%) by weight was recorded in T_2, and the highest reduction of fruit infestation

over control was 92.48%. As a result, the order of efficacy of management practices in terms of fruit infestation reduction is $T_2>T_1>T_3>T_7>T_5>T_6>T_4>T_8$. At late fruiting stage, the lowest fruit infestation (11.98%) by weight was recorded in T_2, and the highest reduction of fruit infestation over control was 86.63%. As a result, the order of efficacy of management practices in terms of fruit infestation reduction is $T_2>T_1>T_3>T_7>T_5>T_6>T_4>T_8$.

In terms of edible portion of infested bitter gourd fruit, the highest edible portion of infested bitter gourd (66.58%) was recorded in T_2 and the highest increase of edible portion of infested bitter gourd over control was 85.06%. As a result, the order of efficacy in terms of increase the edible portion of infested bitter gourd fruit at early fruiting stage is $T_2>T_1>T_3>T_7>T_5>T_6>T_4>T_8$. In case of mid fruiting stage, the highest edible portion of infested bitter gourd (75.25%) was recorded in T_2 and the highest increase of edible portion of infested bitter gourd over control was 91.07%. As a result, the order of efficacy in terms of increase the edible portion of infested bitter gourd fruit at mid fruiting stage is $T_2>T_1>T_3>T_7>T_5>T_6>T_4>T_8$. At late fruiting stage, the highest edible portion of infested bitter gourd (75.84%) was recorded in T_2 and the highest increase of edible portion of infested bitter gourd over control was 88.30%. As a result, the order of efficacy in terms of increase the edible portion of infested bitter gourd fruit at late fruiting stage is $T_2>T_1>T_3>T_7>T_5>T_6>T_4>T_8$.

In single fruit weight, the highest single fruit weight (86.04g) was recorded in T_2 and the highest increase of single fruit weight over control was 50.10%. As a result, the order of efficacy in increasing single fruit weight of bitter gourd is $T_2>T_1>T_3> T_7> T_5> T_6> T_4> T_8$.

In case of number of fruit per plot, the highest number of fruits plot^{-1} (62.33 fruits/plot) was recorded in T_2 and the highest increase of number of fruits plot^{-1} over control was 48.66%. As a

result, the order of efficacy in increasing number of fruits plot^{-1} of bitter gourd is T_2>T_1>T_3> T_7> T_5> T_6> T_4> T_8.

In case of length of single healthy fruit, the highest healthy bitter gourd length (20.66 cm) was recorded in T_2 and the maximum increase of fruit length over control was 26.91%. As a result, the order of efficacy in increasing healthy bitter gourd length is T_2>T_1>T_3> T_7> T_5> T_6> T_4> T_8. And for the girth of single healthy fruit, the highest healthy bitter gourd girth (12.64 cm) was recorded in T_2 and the maximum increase of fruit girth over control was 21.60%. As a result, the order of efficacy in increasing the girth of healthy bitter gourd is T_2>T_1>T_3> T_7> T_5> T_6> T_4> T_8.

In terms of length of single infested fruit, the highest infested fruit length (17.99 cm) was recorded in T_2 and the maximum increase of fruit length over control was 31.79%. As a result, the order of efficacy in increasing the length of infested bitter gourd is T_2>T_1>T_3> T_7> T_5> T_6> T_4> T_8. And for the girth of single infested fruit, the highest infested bitter gourd girth (11.20 cm) was recorded in T_2 and the maximum increase of fruit girth over control was 26.55%. As a result, the order of efficacy in increasing the girth of healthy bitter gourd is T_2>T_1>T_3> T_7> T_5> T_6> T_4> T_8.

Considering the yield of bitter gourd, the highest yield (17.87 ton/ha) was produced in T_2 and the maximum increase of yield over control was 290.17%. As a result, the order of efficacy in increasing the yield of bitter gourd is T_2>T_1>T_3> T_7> T_5> T_6> T_4> T_8.

Comparative study showed that, poison bait trap was more effective than pheromone trap in terms of capturing adult cucurbit fruit flies throughout the cropping season, where in case of poison bait trap the average number of adult cucurbit fruit files captured per trap was 50.00 cucurbit fruit files and in case of pheromone trap this number was 19.00 cucurbit fruit flies.

The highest benefit cost ratio (BCR) (2.47) was calculated in T_2 (poison bait trap), where the total adjusted net return was counted as benefit. This was followed by T_1 (pheromone trap) (1.63) and 1.32 in T_3 (bait spray). The minimum BCR (0.30) was calculated in T_4 (spinosad spray).

Considering the number of cucurbit fruit flies captured in different traps from bitter gourd field, package 1 performed as the best IPM package (36.00 flies) in capturing cucurbit fruit flies. Whereas the lowest performance showed in package 5 (10.22 flies). Package 8 and package 10 did not capture any fruit fly. As a result, the order of efficacy of different IPM packages in terms of capturing cucurbit fruit flies by number is Package 1> Package 2> Package 7> Package 6> Package 4> Package 3> Package 9> Package 5> Package 8> Package 10.

In the term of fruit infestation by number at early fruiting stage, package 1 performed as the best IPM package (22.44%) in terms of fruit infestation by cucurbit fruit flies by number in bitter gourd field. Whereas the lowest performance showed in package 10 (89.18%) in terms of fruit infestation by cucurbit fruit flies by number in bitter gourd field. As a result, the order of efficacy of different IPM packages in terms of fruit infestation by cucurbit fruit flies by number in bitter gourd field at early fruiting stage is Package 1> Package 2> Package 7> Package 6> Package 4> Package 3> Package 9> Package 8> Package 5> Package 10. In case of mid fruiting stage, package 1 performed as the best IPM package (16.66%) in terms of fruit infestation by cucurbit fruit flies by number in bitter gourd field. Whereas the lowest performance showed in package 10 (59.63%) in terms of fruit infestation by cucurbit fruit flies by number in bitter gourd field. As a result, the order of efficacy of different IPM packages in terms of fruit infestation by cucurbit fruit flies by number in bitter gourd field at mid fruiting stage is Package 1> Package 2> Package 7> Package 6> Package 4> Package 3> Package 9> Package 8> Package 5> Package 10. And in

late fruiting stage, package 1 performed as the best IPM package (13.68%) in terms of fruit infestation by cucurbit fruit flies by number in bitter gourd field. Whereas the lowest performance showed in package 10 (70.42%) in terms of fruit infestation by cucurbit fruit flies by number in bitter gourd field. As a result, the order of efficacy of different IPM packages in terms of fruit infestation by cucurbit fruit flies by number in bitter gourd field at late fruiting stage is Package 1> Package 2> Package 7> Package 6> Package 4> Package 3> Package 9> Package 8> Package 5> Package 10.

In term of fruit infestation by weight at early fruiting stage, package 1 performed as the best IPM package (11.83%) in terms of fruit infestation by cucurbit fruit flies by weight in bitter gourd field. Whereas the lowest performance showed in package 10 (92.46%) in terms of fruit infestation by cucurbit fruit flies by weight in bitter gourd field. As a result, the order of efficacy of different IPM packages in terms of fruit infestation by cucurbit fruit flies by weight in bitter gourd field at early fruiting stage is Package 1> Package 2> Package 7> Package 6> Package 4> Package 3> Package 9> Package 8> Package 5> Package 10. In case of mid fruiting stage, package 1 performed as the best IPM package (17.37%) in terms of fruit infestation by cucurbit fruit flies by weight in bitter gourd field. Whereas the lowest performance showed in package 10 (86.48%) in terms of fruit infestation by cucurbit fruit flies by weight in bitter gourd field. As a result, the order of efficacy of different IPM packages in terms of fruit infestation by cucurbit fruit flies by weight in bitter gourd field at mid fruiting stage is Package 1> Package 2> Package 7> Package 6> Package 4> Package 3> Package 9> Package 8> Package 5> Package 10. And in late fruiting stage, package 1 performed as the best IPM package (25.87%) in terms of fruit infestation by cucurbit fruit flies by weight in bitter gourd field. Whereas the lowest performance showed in package 10 (83.13%) in terms of fruit infestation by cucurbit fruit flies by weight in

bitter gourd field. As a result, the order of efficacy of different IPM packages in terms of fruit infestation by cucurbit fruit flies by weight in bitter gourd field at late fruiting stage is Package 1> Package 2> Package 7> Package 6> Package 4> Package 3> Package 9> Package 8> Package 5> Package 10.

In terms of edible portion of infested bitter gourd at early fruiting stage, the highest edible portion of infested bitter gourd (90.75%) was recorded in Package 1in the field, where the highest increase of edible portion of infested bitter gourd over control was 160.49%. As a result, the order of efficacy in terms of increase the edible portion of infested bitter gourd fruit at early fruiting stage is Package 1> Package 2> Package 7> Package 6> Package 4> Package 3> Package 9> Package 8> Package 5> Package 10. In case of mid fruiting stage, the highest edible portion of infested bitter gourd (87.67%) was recorded in Package 1in the field, where the highest increase of edible portion of infested bitter gourd over control was 468.92%. As a result, the order of efficacy in terms of increase the edible portion of infested bitter gourd fruit at mid fruiting stage is Package 1> Package 2> Package 7> Package 6> Package 4> Package 3> Package 9> Package 8> Package 5> Package 10. And in late fruiting stage, the highest edible portion of infested bitter gourd (92.91%) was recorded in Package 1in the field, where the highest increase of edible portion of infested bitter gourd over control was 548.81%. As a result, the order of efficacy in terms of increase the edible portion of infested bitter gourd fruit at late fruiting stage is Package 1> Package 2> Package 7> Package 6> Package 4> Package 3> Package 9> Package 8> Package 5> Package 10.

Considering the length of single healthy fruit at early fruiting stage, the highest healthy bitter gourd length (21.61 cm) was recorded in Package 1 in the field, where the maximum increase of fruit length over control was 38.88%. As a result, the order of efficacy in increasing healthy

bitter gourd length at early fruiting stage is Package 1> Package 2> Package 7> Package 6> Package 4> Package 3> Package 9> Package 8> Package 5> Package 10. In case of mid fruiting stage, the highest healthy bitter gourd length (23.22 cm) was recorded in Package 1 in the field, where the maximum increase of fruit length over control was 45.85%. As a result, the order of efficacy in increasing healthy bitter gourd length at mid fruiting stage is Package 1> Package 2> Package 7> Package 6> Package 4> Package 3> Package 9> Package 8> Package 5> Package 10. And in late fruiting stage, the highest healthy bitter gourd length (22.75 cm) was recorded in Package 1 in the field, where the maximum increase of fruit length over control was 45.18%. As a result, the order of efficacy in increasing healthy bitter gourd length at late fruiting stage is Package 1> Package 2> Package 7> Package 6> Package 4> Package 3> Package 9> Package 8> Package 5> Package 10.

In case of girth of single healthy fruit at early fruiting stage, the highest healthy bitter gourd girth (12.78 cm) was recorded in Package 1 in the field, where the maximum increase of fruit girth over control was 43.43%. As a result, the order of efficacy in increasing the girth of healthy bitter gourd at early fruiting stage is Package 1> Package 2> Package 7> Package 6> Package 4> Package 3> Package 9> Package 8> Package 5> Package 10. In case of mid fruiting stage, the highest healthy bitter gourd girth (14.05 cm) was recorded in Package 1 in the field, where the maximum increase of fruit girth over control was 41.06%. As a result, the order of efficacy in increasing the girth of healthy bitter gourd at mid fruiting stage is Package 1> Package 2> Package 7> Package 6> Package 4> Package 3> Package 9> Package 8> Package 5> Package 10. And in late fruiting stage, the highest healthy bitter gourd girth (13.24 cm) was recorded in Package 1 in the field, where the maximum increase of fruit girth over control was 40.55%. As a result, the order of efficacy in increasing the girth of healthy bitter gourd at late fruiting stage is

Package 1> Package 2> Package 7> Package 6> Package 4> Package 3> Package 9> Package 8> Package 5> Package 10.

Considering the length of single infested fruit at early fruiting stage, the highest healthy bitter gourd length (18.93 cm) was recorded in Package 1 in the field, where the maximum increase of fruit length over control was 46.97%. As a result, the order of efficacy in increasing infested bitter gourd length at early fruiting stage is Package 1> Package 2> Package 7> Package 6> Package 4> Package 3> Package 9> Package 8> Package 5> Package 10. In case of mid fruiting stage, the highest infested bitter gourd length (19.68 cm) was recorded in Package 1 in the field, where the maximum increase of fruit length over control was 42.71%. As a result, the order of efficacy in increasing infested bitter gourd length at mid fruiting stage is Package 1> Package 2> Package 7> Package 6> Package 4> Package 3> Package 9> Package 8> Package 5> Package 10. And in late fruiting stage, the highest infested bitter gourd length (19.29 cm) was recorded in Package 1 in the field, where the maximum increase of fruit length over control was 43.10%. As a result, the order of efficacy in increasing infested bitter gourd length at late fruiting stage is Package 1> Package 2> Package 7> Package 6> Package 4> Package 3> Package 9> Package 8> Package 5> Package 10.

In term of girth of single infested fruit at early fruiting stage, the highest infested bitter gourd girth (9.88 cm) was recorded in Package 1 in the field, where the maximum increase of fruit girth over control was 46.15%. As a result, the order of efficacy in increasing the girth of infested bitter gourd at early fruiting stage is Package 1> Package 2> Package 7> Package 6> Package 4> Package 3> Package 9> Package 8> Package 5> Package 10. In case of mid fruiting stage, the highest infested bitter gourd girth (10.58 cm) was recorded in Package 1 in the field, where the maximum increase of fruit girth over control was 30.94%. As a result, the order of efficacy in

increasing the girth of infested bitter gourd at mid fruiting stage is Package 1> Package 2> Package 7> Package 6> Package 4> Package 3> Package 9> Package 8> Package 5> Package 10. And in late fruiting stage, the highest infested bitter gourd girth (10.24 cm) was recorded in Package 1 in the field, where the maximum increase of fruit girth over control was 39.70%. As a result, the order of efficacy in increasing the girth of infested bitter gourd at late fruiting stage is Package 1> Package 2> Package 7> Package 6> Package 4> Package 3> Package 9> Package 8> Package 5> Package 10.

In term of total number of fruit per plot, the highest number of fruit per plot (76.33 fruits/plot) was recorded in Package 1 in the field, where the maximum increase of number of fruit per plot over control was 138.53%. As a result, the order of efficacy in increasing the number of fruit per plot is Package 1> Package 2> Package 7> Package 6> Package 4> Package 3> Package 9> Package 8> Package 5> Package 10.

In case of single fruit weight, the highest single fruit weight (50.13 g) was recorded in Package 1 in the field, where the maximum increase of single fruit weight over control was 91.48%. As a result, the order of efficacy in increasing the single fruit weight is Package 1> Package 2> Package 7> Package 6> Package 4> Package 3> Package 9> Package 8> Package 5> Package 10.

Considering the yield of bitter gourd, the highest yield (12.76 ton/ha) was recorded in Package 1 in the field, where the maximum increase of yield over control was 357.35%. As a result, the order of efficacy in increasing the yield of bitter gourd is Package 1> Package 2> Package 7> Package 6> Package 4> Package 3> Package 9> Package 8> Package 5> Package 10.

CONCLUSION

From this study it can be concluded that cucurbit fruit fly can attack all types of cucurbitaceous crops. But the infestation become low in kharif season and high in rabi season. Not only that, among different types of cucurbitcrops cucurbit fruit fly attacked more in bitter gourd and less in sweet gourd. Life cycle of cucurbit fruit flies depends on temperature and relative humidity. At laboratory condition where temperature (25℃) and relative humidity (80%) strongly maintained, cucurbit fruit flies showed long life cycle whereas at room temperature and relative humidity they showed short life cycle. In field condition at kharif 2 season, cucurbit fruit flies shows short life cycle. The incidence of cucurbit fruit fly and infestation of bitter gourd by cucurbit fruit fly varied significantly among the treatments. The overall study revealed that the highest performance was achieved from T_2. It might increase number of fruit per plant, weight of single fruit, edible portion of infested fruit, length of fruit, girth of fruit and yield. It also reduced fruit infestation. Considering the results of the present study, it can be concluded that, T_2 may be used for the management of cucurbit fruit fly attacking cucurbitaceous vegetables. The incidence of cucurbit fruit fly and infestation of bitter gourd by cucurbit fruit fly was significantly varied among the IPM packages. The overall study revealed that the highest performance was achieved from IPM Package 1. It might reduce the infestation of fruit by number and by weight, and increase number of fruit per plant, weight of single fruit, edible portion of infested fruit, length of fruit, girth of fruit and yield. Considering the results of the present study, it can be concluded that IPM Package 1may be used for the management of cucurbit fruit fly.

Considering the findings of the study the following recommendations can be drawn:

1. Bitter gourd was the most susceptible host for cucurbit fruit fly.
2. To minimize the use of chemical insecticides in cucurbit fruit fly control programmes, Poison bait trap can play a significant role. It should be adopted in large scale production of chemical free cucurbitaceous vegetables.
3. Pheromone trap along with poison bait trap used as IPM tools should be practiced in commercial cucurbit vegetable especially bitter gourd cultivation against cucurbit fruit fly.
4. IPM tools as pheromone trap along with poison bait trap is needed more experiment in different cucurbit vegetable field.
5. Further study is needed in different species of cucurbits.
6. Further study is also needed in different locations of Bangladesh and different seasons for accuracy of the results obtained from the present experiment.
7. More experiments are needed including different combinations of eco-friendly management practices to manage cucurbit fruit flies in different cucurbitaceous vegetables.

CHAPTER VI

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CHAPTER VII

APPENDIXES

Appendix I. The physical and chemical characteristics of soil the experimental site as observed prior to experimentation (0-15 cm depth).

Mechanical composition:

Soil parameters	Observed values
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.07
Phosphorus	22.08 µg/g soil
Sulphur	25.98 µg/g soil
Magnesium	1.00 mcq/100 g soil
Boron	0.48 µg/g soil
Copper	3.54 µg/g soil
Zinc	3.32 µg/g soil

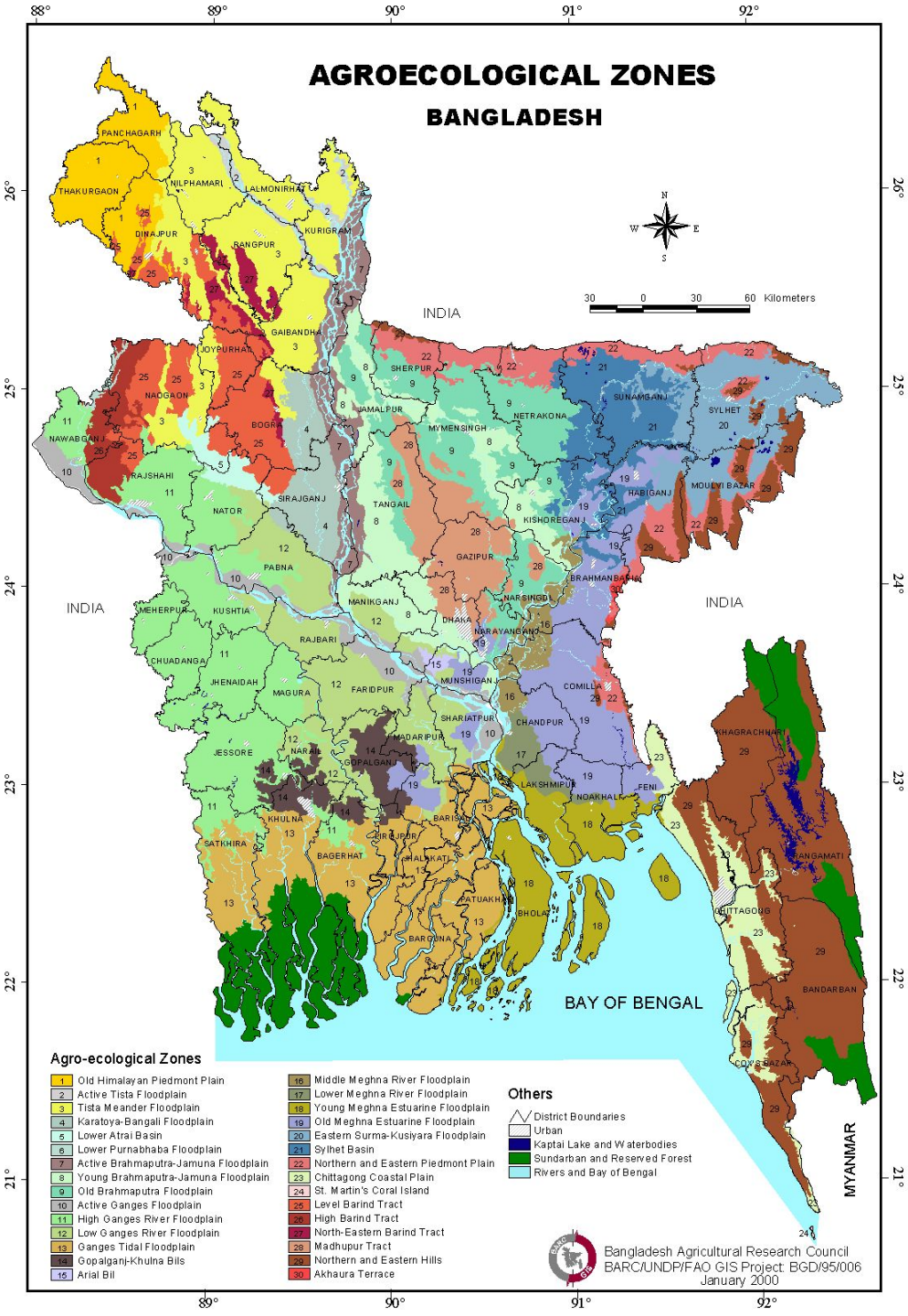
Source: Soil Resources Development Institute (SRDI), Khamarbari, Dhaka.

Appendix II: Monthly record of air temperature, rainfall and relative humidity of the experimental site during the period from November 2012 to February 2013

Date/Week	Temperature		Relative humidity (%)	Rainfall (mm) (Total)
	Maximum	Minimum		
November	25.1	15.8	73.1	2.08
December	25	13	60.7	0
January	28.2	18.4	60.3	3.50
February	33.8	22.3	52.2	4.53
March	34.5	24.5	51.65	4.87
April	35.8	26	50.05	6.03

Source: Bangladesh Meteorological Department (Climate and Weather Division), Agargoan, Dhaka- 1207

Appendix III. Experimental location on the map of Agro-ecological Zones of Bangladesh.



Source: Bangladesh Agricultural Research Council, Khamarbari, Dhaka.

Appendix IV. Cost incurred per hectare in different control measures applied against cucurbit fruit fly on bitter gourd during Kharif I, 2016 at SAU Dhaka

Treatment	Items of expenditure	Cost (Tk)
T_1=Pheromone trap(Cue-lure + soap) @ 4 days interval	Total no. of labors for giving treatment 15x250[a]	3750.00
	Pheromone trap set 40x 30[b]	1200.00
	Lure 40x 16[c]	640.00
	Wheel powder	360.00
	Irrigation	3000.00
	Land cost[h]	200000.00
	Harvesting cost 22x250[a]	5500.00
	Total cost	**214450.00**
T_2=Poison bait trap(2 gm Sevin 85 WP + 100 gm Mashed Sweet Gourd + 10 ml Molasses) @ 4 days interval	Total no. of labors for giving treatment 15x250[a]	3750.00
	Earthen pot	750.00
	Sweet gourd	500.00
	Molasses	250.00
	Sevin 85 SP 5x105[d]	525.00
	Irrigation	3000.00
	Land cost[h]	200000.00
	Harvesting cost 22x250[a]	5500.00
	Total cost	**214275.00**
T_3=Bait spray (1L water + 10 ml Molasses + 1 ml Malathion) @ 7 days interval,	Total no. of labors for spraying insecticide 15x250[a]	3750.00
	Malathion 57 EC 15x 85[f]	1275.00
	Molasses	5000.00
	Irrigation	3000.00
	Land cost[h]	200000.00
	Harvesting cost 22x250[a]	5500.00
	Total cost	**218525.00**
T_4=Spinosad (0.08 ml per liter of water) @ 7 days interval	Total no. of labors for spraying insecticide 15x250[a]	3750.00
	Spinosad (for 8 sprays) x 0.3[e]	7500.00
	Irrigation	3000.00
	Land cost[h]	200000.00
	Harvesting cost 22x250[a]	5500.00
	Total cost	**219750.00**
T_5= Neem oil (3 ml neem oil + 10 ml soap) @ 7 days interval	Total no. of labors for spraying insecticide 15x250[a]	3750.00
	Neem oil[g]	1350.00
	Trix	4500.00
	Irrigation	3000.00
	Land cost[h]	200000.00
	Harvesting cost 22x250[a]	5500.00
	Total cost	**218100.00**
T_6= Neem seed kernel extract (3 ml neem seed kernel extract + 10 ml soap) @ 7 days interval	Total no. of labors for spraying insecticide 15x250[a]	3750.00
	Neem seed kernel extract	1400.00
	Trix	4500.00
	Irrigation	3000.00
	Land cost[h]	200000.00
	Harvesting cost 22x250[a]	5500.00

	Total cost	**218150.00**
T_7= Malathion 57 EC (1 ml + 1 liter of water) @ 7 days interval	Total no. of labors for spraying insecticide 15x250[a] Malathion 57 EC 16x85[f] Molasses Irrigation Land cost[h] Harvesting cost 22x250[a] **Total cost**	3750.00 1360.00 5000.00 3000.00 200000.00 5500.00 **218610.00**
T_8 (Untreated control)	Irrigation Land cost[h] Harvesting cost 22x250[a] **Total cost**	3000.00 200000.00 5500.00 **208500.00**

[a] = Labor cost 250.00 Tk/day; [b] = Pheromone trap set 30.00 Tk/set; [c] = Lure 16 Tk/lure; [d] = Sevin (85 SP) 100 gm = 105 Tk.; [e] = Spinosad 20 ml = 205 Tk.; [f] = Malathion (57 EC) 100 ml = 85 Tk.; [g]= Neem oil = 60 tk/lit.; [h]= Land cost= Taka for land lease, land preparation and fertilizer.