EFFECTIVENESS OF TRAPS AND INSECTICIDES FOR THE MANAGEMENT OF CUCURBIT FRUIT FLY

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DHAKA-1207

JUNE, 2017

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Reg. No.:11-04655

A Thesis

Submitted to the Department of **Entomology**
Sher-e-Bangla Agricultural University, Dhaka
In partial fulfillment of the requirements
for the degree
of

MASTER OF SCIENCE (MS)

IN

ENTOMOLOGY

SEMESTER: JANUARY - JUNE, 2017

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CERTIFICATE

This is to certify that thesis entitled **"EFFECTIVENESS OF TRAPS AND INSECTICIDES FOR THE 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 **MASTER OF SCIENCE (MS) IN ENTOMOLOGY**, embodies the result of a piece of bona fide research work carried out by **ARAFAT SULTANA FERDOUSI, Registration no.11-04655** under my supervision and guidance. No part of the thesis has been Submitted earlier 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 2017
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Dedicated To

My Beloved Parents

ACKNOWLEDGEMENT

Alhamdulillah, all praises are due to the almighty **Allah Rabbul Al-Amin** for His gracious kindness and infinite mercy in all the endeavors the author to let her successfully complete the research work and the thesis leading to the degree Master of Science.

The author would like to express her heartfelt gratitude and most sincere appreciations to her Supervisor Professor Dr. Md. Abdul Latif Department of Entomology Sher-e-Bangla Agricultural University, Dhaka, for his valuable guidance, advice, immense help, encouragement and support throughout the study. Likewise grateful appreciation is conveyed to her Co-Supervisor Associate Professor Dr. Mst. Nur Mohal Akhter Banu Department of Entomology Sher-e-Bangla Agricultural University, Dhaka, for her constant encouragement, cordial suggestions, constructive criticisms and valuable advice to complete the thesis.

The author would like to express her deepest respect and boundless gratitude to all the respected teachers of the Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka, for their valuable teaching, sympathetic co-operation, and inspirations throughout the course of this study and research work.

The author wishes to extend her special thanks to her class mates and friends and roommates for their keen help as well as heartiest co-operation and encouragement during experimentation.

The author is deeply indebted and grateful to her parents, brothers, sisters, and sister in law relatives who continuously prayed for her success and without whose love, affection, inspiration and sacrifice this work would not have been completed.

Finally the author appreciates the assistance rendered by the staff members of the Department of Entomology and central farm, Sher-e-Bangla Agricultural University, Dhaka, who have helped her lot during the period of study.

June 2017 ***The Author***

EFFECTIVENESS OF TRAPS AND INSECTICIDES FOR THE MANAGEMENT OF CUCURBIT FRUIT FLY

ABSTRACT

A field experiment was carried out during December 2016 to March 2017 at Sher-e-Bangla Agricultural University farm to find out the comparative effect of traps and insecticides for the management of cucurbit fruit fly, *Bactrocera cucurbitae* on cucumber. Eight treatments, *viz*. T_1 (bait trap), T_2 (pheromone trap), T_3 (spraying Voliam flexi @ 0.5 ml/liter water at 10 days interval), T_4 (bait trap + pheromone trap), T_5 (bait trap + insecticide), T_6 (pheromone trap + Voliam flexi), T_7 (bait trap + pheromone trap + Voliam flexi) and T_8 (untreated control) were used for the management of cucurbit fruit fly infesting cucumber. Sevin 85SP was used with mashed sweet gourd in bait trap. The experiment was laid out in Randomized Block Design (RCBD) with three replications. Results revealed that the highest healthy and total fruit yield (18.24 t ha^{-1} and 21.22 t ha^{-1} respectively) was found from T_7 (bait trap + pheromone trap + Voliam flexi) and the lowest healthy and total fruit yield (5.21 and 14.44 t ha^{-1} respectively) was found from control treatment (T_8). The lowest infested fruit yield (2.68 t ha^{-1}) was obtained from T_7 (bait trap + pheromone trap + Voliam flexi). In case of percent reduction of infestation over untreated control, T_7 consisting bait trap + pheromone trap + Voliam flexi, gave the best performance at all growth stages. Spraying voliam flexi 300SC @ 0.5 ml/liter water at 10 days interval in combination with bait and pheromone traps (T_7) was the most effective treatment for the management of cucurbit fruit fly infesting cucumber.

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ABBREVIATIONS AND ACRONYMS

%	=	Percentage
AEZ	=	Agro-Ecological Zone
BBS	=	Bangladesh Bureau of Statistics
BCSRI	=	Bangladesh Council of Scientific Research Institute
Ca	=	Calcium
cm	=	Centimeter
CV %	=	Percent Coefficient of Variation
DAS	=	Days After Sowing
DMRT	=	Duncan's Multiple Range Test
e.g.	=	exempli gratia (L), for example
et al.,	=	And others
etc.	=	Etcetera
FAO	=	Food and Agricultural Organization
g	=	Gram (s)
GM	=	Geometric mean
i.e.	=	id est (L), that is
K	=	Potassium
Kg	=	Kilogram (s)
L	=	Litre
LSD	=	Least Significant Difference
M.S.	=	Master of Science
m^2	=	Meter squares
mg	=	Miligram
ml	=	MiliLitre
NaOH	=	Sodium hydroxide
No.	=	Number
^oC	=	Degree Celceous
P	=	Phosphorus
SAU	=	Sher-e-Bangla Agricultural University
SW	=	Standard week
USA	=	United States of America
var.	=	Variety
viz.	=	Namely
WHO	=	World Health Organization
µg	=	Microgram

CHAPTER I

INTRODUCTION

Bangladesh is principally an agriculture based country. But it has a huge deficit in vegetable production. The annual production of vegetables is 8685,000 million tons (BBS, 2016). A large number of cucurbit vegetables, viz., bottle gourd, bitter gourd, sweet gourd, snake gourd, white gourd, ridge gourd, sponge gourd, kakrol, cucumber etc. are grown in Bangladesh. Among them cucumber is one of the most important vegetable crop in our country. In Bangladesh, the rate of production of snake gourd is 5.537 ton/acre (BBS, 2015). Area covered by bitter gourd was 25522 acre with a total production of 57128 tons (BBS, 2015). Most of the important vegetables are produced in winter and the production in summer is tremendously low (Anon., 1993). Cucurbits occupy 66 per cent of the land under vegetable production in Bangladesh and contribute 18 percent of total vegetable production in both winter and summer season (BBS, 2016).

Cucurbits are infested by several insect pests which are considered to be the significant obstacles for economic production. Among them, cucurbit fruit fly is the serious pest responsible for considerable damage of cucurbits (Butani and Jotwani 1984).

Bactrocera cucurbitae is dominant in all the locations of Bangladesh followed by *Bactrocera tau* and *Dacus ciliatus* (Akhtaruzzaman *et al,* 1999). It prefers to infest young, green, soft-skinned fruits. It inserts the eggs 2 to 4 mm deep in the fruit tissues, and the maggots feed inside the fruit. Pupation occurs in the soil at 0.5 to 15 cm below the soil surface depending on the nature and type of soil (Dhillon *et al*., 2005).

Depending on the environmental conditions and susceptibility of the crop species, the extent of losses varies between 30 to 100 per cent (Pareek and Kavadia, 1994;

Dhillon *et al*., 2005; Shooker *et al*., 2006). This pest is reported to cause 80 percent infestation in cucumber and bottle gourd, 60 percent in bitter gourd and 50 percent in sponge gourd (Gupta and Verma, 1992). Due to its nature of infestation, it is very difficult to control the pest. For controlling this pest, several researchers have worked on the effectiveness of different insecticides for the control of *B. cucurbitae* infesting cucurbits (Babu *et al*., 2002).

A cluster method have been developed and suggested by Kapoor (1993) to control these pests. Each and every method has its positive and negative effects. Among all these methods, the chemical control method is still popular to the Bangladeshi farmers because of its quick and visible results.

Several management options, such as hydrolyzed protein spray, para-pheromone trap, spraying of ailanthus and cashew leaf extract, neem products, bagging of fruits, field sanitation, food baits, and spray of chemical insecticides (Neupane, 2000; Akhtaruzzaman *et al*., 2000; Dhillon *et al*., 2005) have been in use for the management of cucurbit fruit fly, some of them either fail to control the pest and/or are uneconomic and hazardous to non-target organisms and the environment (Neupane, 2000; Dhillon *et al*., 2005).

However, an effective and cheap management strategy against this pest has already been developed, which comprises of sanitation and use of pheromone mass trapping and bait trap. Scientists at the Bangladesh Agricultural Research Institute (BARI) in collaboration with the USAID funded Integrated Pest Management Collaborative 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 (Anon., 2002-2003).

However, alarming consequences of pesticide usage and residual effect on the environment, pragmatic programmer is now needed to minimize the dependency on insecticides without hampering crop production. IPM, undoubtedly since last few years has been a much talked scientific phenomenon in Bangladesh, particularly in the area of the agricultural policy makers.

Considering the impact of chemicals on crops, and the environment, efficacy of different control measures aiming to develop an eco-friendly and sustainable pest management system in cucurbits is urgently needed. And considering the hazardous impact of chemicals on non-target organisms and the environment, present studies were undertaken to assess the losses caused by B. cucurbitae and efficacy of different control measures aiming to develop an eco-friendly and sustainable pest management system in cucurbit .

Considering the above facts view in mind, the experiment has been undertaken with the following objectives:

1. To study the infestation intensity of fruit fly in cucumber at field.
2. To find out a effective trap for the management of cucurbit fruit fly infesting cucumber for the development of IPM practices.
3. To evaluate the effectiveness of traps and insecticide against cucurbit fruit fly.

CHAPTER II

REVIEW OF LITERATURE

Cucurbit fruit fly, *Bactrocera cucurbitae* Coquillett has been reported the most prominent pest of cucurbitaceous vegetables over the last several decades (Manjunathan, 1997; Yubak and Mandal, 2000). They reported that several abiotic and biotic factors limited the production and productivity of cucurbits, of which cucurbit fruit fly (depending on the environmental conditions and susceptibility of the crop species) cause much damage and the extent of losses varies between 30 to 100% (Shooker *et al*., 2006). The relevant information pertaining to origin, distribution, biology and seasonal abundance, host range, host preference, nature of damage of these pest and yield loss due to their attack and management of fruit fly have been discussed in this section.

2.1 Classification of Insect

Kingdom: Animalia

Phylum: Arthropoda

Class: Insecta

Order: Diptera

Family: Tephritidae

Genus: *Bactrocera*

Species: *B. curcurbitae*

Synonyms

Chaetodacus cucurbitae (Coquillett)

Dacus cucurbitae (Coquillett)

Strumeta cucurbitae (Coquillett)

Zeugodacus cucurbitae (Coquillett)

2.2 Origin and distribution

The distribution of particular species is limited perhaps due to physical, climate and gross vegetational factors, but most likely due to host specificity. Fruit fly is considered to be the native of oriental, probably India and south east Asia and it was first discovered in the Yaeyama Island of Japan in 1919 (Anon., 1987). However, the fruit fly is widely distributed in India, Bangladesh, Pakistan, Myanmar, Nepal, Malaysia, China, Philippines, Formosa (Taiwan), Japan, Indonesia, East Africa, Australia, and Hawaiian Island (Alam, 1965). It was discovered in Solomon Islands in 1984, and is now widespread in all the provinces, except Makira, Rennell-Bellona and Temotu (Eta, 1985). In the Commonwealth of the Northern Mariana Islands, it was detected in 1943 and eradicated by sterile-insect release in 1963 (Mitchell, 1980), but re-established from the neighboring Guam in 1981 (Wong *et al.*, 1989). It was detected in Nauru in 1982 and eradicated in 1999 by male annihilation and protein bait spraying, but was re-introduced in 2001 (Hollingsworth and Allwood, 2002). Although it is found in Hawaii, it is absent from the continental United States (Weems and Heppner, 2001). In July 2010, fruit flies were discovered in traps in Sacramento and Placer counties.

The distribution of a particular species is limited perhaps due to physical, climatic and gross vegetational factors but most likely due to host specificity. Such species may become widely distributed when their host plant are widespread, either naturally or cultivation by man (Kapoor, 1993). 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, subtropical, 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.

The melon fruit fly is distributed all over the world, but India is considered as its native home. Two of the world most damaging tephritids, *Bactrocera dorsalis* and *B. cucurbitae,* are widely distributed in Malaysia and other South East Asian countries (Vijaysegaran, 1987). Aktheruzzaman (1999) *Bactrocera cucurbitae*, *Bactrocera tau and Bactrocera ciliates* have been currently identified in Bangladesh of which *Bactrocera ciliates* is a new record. *B. cucurbitae* is dominant in all the locations of Bangladesh followed by *B. tau* and *B. ciliates.*

2.3 Host range

The cucurbit fruit fly, *B. cucurbitae* (Coq.) is a polyphagous that infests as many as 125 plant species most of them belong to Cucurbitaceae and Solanaceae (and Bezzi, 1913; Dhillon *et al.* 2005). Presently, four Asian *Bactrocera* species-*Bactrocera cucurbitae, B. invadens, B. latifrons and B.zonata* Invaded Africa (Mwatawala, *et al.,* 2010; White, 2006). Studies so far have shown that although these invasive *Bactrocera* species are polyphagous, they show preference in host utilization. the host range of *B. invadens* in Africa comprises 72 plant species spread across 28 families (Goergen *et al.*, 2011; Ekesi *et al.,* 2006; Vayssieres *et al.,* 2005).

In West and Central Africa, *B. invadens* is highly polyphagous, infesting wild and cultivated fruit of at least 46 species from 23 families with guava, mango and citrus being the preferred hosts. *Terminalia catappa* (Tropical almond), *Irvingia gabonensis* (African wild mango), and *Vitellaria paradoxa* (Sheanut) are important wild hosts with high infestations (Goergen *et al.*, 2011). In Tanzania, *B. invadens* was found to infest 15 fruit species of which the major commercial fruits: Mango, Loquat and guava were the preferred hosts. Other major hosts were *Flacourtia indica* (Governor's plum) and *Annona muricata* (Soursop) (Mwatawala *et al.,* 2006). *B. latifrons* have been found to utilize 12 Solanaceous fruit species and 3 cucurbit species in Tanzania (Mziray *et al*., 2010). According to them, *Solanum incanum, S. sodomeum* (Sodom apple) and *Lycopersicon* *pimpinellifolium* (Cherry tomato) were recorded as wild hosts, the rest were cultivated hosts.The study revealed that *S. nigrum* (Black nightshade), *S. anguivi* (African eggplant) and *S. scabrum* was the preferred host; however *S. scabrum* was the most preferred host among the cultivated Solanaceae.

Vayssieres *et al.,* (2007) reported *B. cucurbitae* to be polyphagous in West Africa infesting 17 fruits pecies however in Reunion Island they found *B. curcubitae* to be oligophagous depending primarily on Cucurbitaceae family. Generally, there preferred hosts are members of Cucurbitaceae.

Mwatawala *et al.* (2010) found *B. cucurbitae* to be polyphagous utilizing 19 hosts out of which 11 belong to Cucurbitae family. According to them melon *(Cucumis melo*) is the most preferred host while *Momordica trifoliate* was the most important wild host. For all others both cultivated and wild hosts, infestation rate ranged from 37 to 157 flies/Kg fruit. The fruiting season of these plants were also the period of highest population density for *B. cucurbitae*.

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 anguina* and *T. cucumeria)* are the most preferred hosts. However, White and Harris (1993) 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, Chinese bananas and the juice exuding from sweet corn.

The melon fly has a mutually beneficial association with the Orchid, Bulbophyllum paten, which produces zingerone. In Bangladesh, fruits of melon

(*Cucumis melo*), sweet gourd (*Cucurbita maxima*), snake gourd (*Trichosanthes cucumerina, Benincasa hispida*), watermelon (*Citrullus lanatus*), ivy gourd (*Coccinia grandis),* cucumber (*Cucumis sativus, Cucumis trigonus*), white-flowered gourd (*Lagenaria siceraria*), luffa (*Luffa aegyptiaca*) balsam-apple (*Momordica balsamina*), bitter gourd (*Momordica charantia)* etc. are infested by this species (Khan *et al*., 2007; Saha *et al.*, 2007; Wadud *et al.*, 2005). Losses due to this fruit fly infestation were estimated from 10 to 30% of annual agricultural produces in the country (Naqvi, 2005).

2.4 Seasonal abundance

The population of fruit fly fluctuates throughout the year and the abundance of fruit fly population varies from month to month, season to season, even year to year depending upon various environmental factors, the fly has been observed to be active in the field almost throughout the year where the weather is equable (Narayan and Batra, 1960). They reported that most of the fruit fly species are more or less active at temperatures ranging between 12°C - 15°C and become inactive below 10° C. Cucurbit fruit flies normally increases their multiplication when the temperatures goes below 15°C and relative humidity varies from 60-70% (Alam, 1965). The abundance of fruit fly in cuelure baited trap was observed throughout the year, with two peaks in summer and kharif coinciding with 14 SW (standard week) and 43 SW, respectively in bitter gourd. In kharif, maximum damage (62.70%) occurred in 15, 45 SW, and second peak with 49.70% damage observed during 45, 15 SW periods. The temperature (maximum and minimum) had significantly positive correlation with abundance, damage and pupal population; temperature during one, two and three preceding weeks had slightly greater impact than that of the prevailing week. Other abiotic factors had non-significant effect on adult activity, damage and pupal population. (Raghuvanshi *et al.,* 2010).

Bangladesh is a tropical country and the temperature remains quite high in summer but not very cold in winter. The optimal temperature for the development of *B. cucurbitae* ranged from 20^{o}C to 28^{o}C (Wu *et al,* 2000). Studies on the population dynamics of *C. capitata* have shown that the main factor affecting population build up in the tropics is fruit abundance and availability, whereas in temperate areas low winter temperatures also play a major role (Papadopoulos, 1999 and Katsoyannos *et al.*, 1998). The presence of abundant backyard garden cucurbit vegetables during winter season in Ganakbari area was responsible for the presence of high level melon fly population. Ye (2001) reported that the area planted with fruit trees, the fruit production yields, and the fruiting period can all affect oriental fruit fly population size. In the field without pesticide treatments 50-70% of the cucurbit fruits are infested (Singh *et al.*, 2000 and Hollingworth *et al.*, 1997). The infested fruits in the field may serve as reservoir for continuous presence of the fly if not treated the fruits or removed or bagged the infested fruits.

It is necessary to point out that, since the cue lure that used in the present study which only attracts *B. cucurbitae* male adults, the fly population studied in the present research was for the male population. Regarding the 1:1 sex rate for *B. cucurbitae* adults (He *et al.*, 2002), the entire *B. cucurbitae* population could be estimated based on the size of the male adult populations.

2.5 Nature of damage

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 pseudopunctures (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 more than 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.,* 2005). The extent of losses varies 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% (Rabindranath and Pillai, 1986; Gupta and Verma, 1978). The melon fruit fly has 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.

2.6 Rate of infestation and yield loss by fruit fly

According to the reports of Bangladesh Agricultural Research Institute, fruit infestations were 22.48, 41.88 and 67.01 per cent for snake gourd, bitter gourd, and musk melon, respectively (Anon., 1988).

Kabir *et al.* (1991) reported that yield losses due to fruit infestation varies in different fruits and vegetables and it is minimun in cucumber (19.19%) and maximum in sweet gourd (69.96%). The damage caused by fruit fly is the most serious in melon after the first shower in monsoon when it often reaches up to 100%. Other cucurbit might also be infected and the infestation might be reduced up to 50% (Atwal, 1993). Borah and Dutta (1997) studied the infestation of tephritids on the cucurbits in Assam, India and obtained highest fruit fly infestation rate in snake gourd (62.02%). Larger propotion of marketable fruits was obtained from ash gourd in and bottle gourd in summer season. 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.*, 2005; Gupta and Verma, 1992).

2.7 Life cycle of Cucurbit fruit fly

The life cycle from egg to adult requires 14-27 days. Insects are able to grow and develop on a variety of host species which effect on their growth, reproduction and development (Tikkanen *et al.*, 2000). Mukherjee *et al.* (2007) studied the life history of *B. cucurbitae* on sweet gourd and reported pre-oviposition, oviposition, incubation, larval and pupal periods, and adult male and female longevity 11.25, 9.75, 0.81, 12.25, 7.75, 18.25, and 23.50 days, respectively. They also reported that the mean fecundity of fruit fly on this crop was 52.75 female^{-1}.

2.7.1 Eggs

The eggs of the melon fly are slender, white and measure 1/12 inch in length. Eggs are inserted into fruit in bunches of 1 to 37. They hatch in 2 to 4 days. 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%. 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 (Koul and Bhagat, 1994 and Hollingsworth *et al.*, 1997).

2.7.2 Larvae

Heppner (1989) cited detailed description of larvae. The larval period lasts from 6 to 11 days, with each stage lasting 2 or more days. Duration of larval development is strongly affected by host. The larval period lasts for 3 to 21 days (Renjhan, 1949; Narayanan and Batra, 1960; Hollingsworth *et al.*, 1997), 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). Larval feeding damage in fruits is the most damaging (Wadud *et al.,* 2005). Mature attacked fruits develop a water soaked appearance (Calcagno *et al.,* 2002). Young fruits become distorted and usually drop. The larval tunnels provide entry points for bacteria and fungi that cause the fruit to rot (Collins *et al.*, 2009). These maggots also attack young seedlings, succulent tap roots, stems and buds of host plants such as mango, guava, cucumber, custard apple and others (Weldon *et al.*, 2008). 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.

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 (Jackson *et al.*, 1998).

2.7.3 Pupae

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).

2.7.4 Adults

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 premating 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). Meansingle 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 mating (Miyatake, 1995). However, longer developmental period was not necessarily associated with greater fecundity and longevity (Miyatake, 1996).

2.8 Management of fruit fly

The utilization of pre-harvest management practices is important to reduce direct losses and to increase efficacy of post-harvest quarantine treatments. Since the discovery of the melon fly in Hawaii a number of methods have been employed in attempts to reduce or prevent damage by this pest. These include: 1) mechanical control, 2) cultural control, 3) biological control and 4) chemical control (Dhillon *et al.*, 2005). Keeping in view the importance of the pest and crop, melon fruit fly management could be done using local area management and wide area management. The melon fruit fly can successfully be managed over a local area by bagging fruits, field sanitation, protein baits, cue lure traps, growing fruit fly resistant genotypes, augmentation of biocontrol agents and soft insecticides. The available literatures on the measures for the controlling of these flies are discussed under the following sub-headings:

2.8.1 Cultural control

Cultural methods of the pest control aim at reducing, insect population encouraging a healthy growth of plants or circumventing the attack by changing various agronomic practices (Chattopadhyay, 1991). The cultural practices used for controlling fruit flies were described by the following headings.

2.8.1.1 Ploughing of soil

In the pupal stage of fruit fly, it pupates in soil and also over winter in the soil. In the winter period, the soil in the field s turned over or given a light ploughing; the pupae underneath are exposed to direct sunlight and killed. They also become a prey to the predators and parasitoids. A huge number of pupae are died due to mechanical injury during ploughing (Kapoor, 1993; Agarwal *et al.*, 1987). The female fruit fly lays eggs and the larvae hatch inside the fruit, it becomes essential to look for the available measures to reduce their damage on fruit. One of the safety measures is the field sanitation (Nasiruddin and Karim, 1992).

2.8.1.2 Field sanitation

Field sanitation is an essential pre requisite to reduce the insect population or defer the possibilities of the appearances of epiphytotics or epizootics (Reddy and Joshi, 1992).

According to Kapoor (1993), in this method of field sanitation, the infested fruits on the plant or fallen on the ground should be collected and buried deep into the soil or Cooked and fed to animals.

Systematic picking and destruction of infested fruits in Proper manner to keep down the population is resorted to reduce the damages caused by fruit flies infesting cucurbits, Guava, mango, peach etc. and many borers of plants (Chattopadhyay, 1991).

2.8.2 Biological Control

Thirty-two species and varieties of natural enemies to fruit flies were introduced to Hawaii between 1947 and 1952 to control the fruit flies. These parasites lay their eggs in the eggs or maggots and emerge in the pupal stage. Only three, *Opius longicaudatus* var. *malaiaensis* (Fullaway), *O. vandenboschi* (Fullaway), and *O. oophilus* (Fullaway), have become abundantly established. These parasites are primarily effective on the oriental and Mediterranean fruit flies in cultivated crops. The most efficacious parasite of the melon fly is *O. fletcheri* (Silvestri). It was introduced in 1916 from India. This parasite attacks the melon fly during the larval stage. Bess *et. al.*, (1961) reported that this parasite killed 20 - 40 percent of fruit fly larvae. It is more effective in reducing populations in wild areas than in cultivated crops.

2.8.3 Mechanical control

2.8.3.1 Bagging of fruits

Sometimes each and every fruit is covered by a paper or cloth bag to block the contact of flies with the fruit thereby protecting from oviposition by the fruit fly and it is quite useful when the flies are within the reach and the number of fruits to be covered and less and it is a tedious task for big commercial orchards (Kapoor, 1993).

Bagging of the fruits against *Bactrocera cucurbitae* greatly promoted fruit quality and the yields and net income increased by 45 to 58% in bitter gourd while 40 to 45% in sponge gourd (Fang, 1989).

Amin (1995) obtained significantly lowest fruit fly infestation (4.61%) in bagged cucumber compared to other chemical and botanical control measures. Covering of fruits by polythene bag is an effective method to control fruit fly in teasel gourd and the lowest fruit fly incidence in teasel gourd occurred in bagging. Fruits (4.2%) while the highest (39.35) was recorded in the fruits of control plot (Anon., 1988).

2.8.3.2 Fruit picking

Systematic picking and destruction of infested fruits in proper manner to keep down the population is resorted to reduce the damages caused by fruit flies infesting cucurbits, guava, mango, peach etc. and many borers of plants (Chattopadhyay, 1991).

2.8.3.3 Wire Netting

Kapoor (1993) reviewed that fine wire netting may sometimes be used to cover small garden. Though it is a costly method, but it can effectively reduce the fruit fly infestation and protect the fruit from injury and deform, and also protects fruit crops against vertebrate pest.

2.8.4 Chemical control

2.8.4.1 Cover spray of insecticide

Bharadiya and Bhut (2017) carried out a field experiments on effect of different insecticides against fruit fly, *Bactrocera cucurbitae* Coquillett infesting sponge gourd during consecutive two years 2014 and 2015. The five different insecticides were evaluated against the fruit fly, *B. cucurbitae* infesting sponge gourd. The insecticides abamectin 0.0025 percent and emamectin benzoate 0.002 percent were found most effective and economic and were statistically at par with each other. The significantly minimum fruit infestation 19.35 percent with 32.01 percent yield increased and net return Rs. 22695/ha was recorded in the treatment of abamectin. While in emamectin benzoate 20.62 percent fruit infestation with 29.10 percent yield increased and Rs. 20625/ha net return was recorded. However, the treatment of dichlorovos 0.07 percent (22.65% fruit infestation with 26.32% increased yield and Rs. 18660/ha net return) was proved next best insecticide.

Oke and Sinon (2013) conducted a field experiment from Oct to Dec in the 2009 and 2010 planting seasons to evaluate the effectiveness of 3 insecticides namely lambda-cyhalothrin, deltamethrin and mercaptothion, to control the melon fruit fly (*Bactrocera cucurbitae*) in the cucumber crop. The results obtained showed that the use of deltamethrin insecticide recorded the lowest number of ovipositor marks, number of pupae and number of emerged melon fruit flies. The number of melon fruit flies that emerged with the use of deltamethrin insecticide was significantly (P. 0.05) decreased by 19.0% and 38.1%, respectively, in 2009 and by 10.0% and 44.4%, respectively, in 2010 compared to that recorded with the use of lambda-cyhalothrin and mercaptothion. The highest number of marketable cucumbers was produced from plots sprayed with deltamethrin; and which was significantly (P. 0.05) increased by 50.5% and 62.9%, respectively, in 2009 and by 29.0% and 50.7%, respectively, in 2010 compared to those obtained when lambda-cyhalothrin and mercaptothion were used. This study showed that deltamethrin insecticide was the most effective, and could be recommended for the control of melon fruit fly in cucumber under field conditions.

A wide range of organophosphoras, carbamate and synthetic pyrethroids of various formulations have been used from time to time against fruit fly (Kapoor, 1993; Nayar *et al.,* 1989). Spraying of conventional insecticide is preferred in destroying adults before sexual maturity and oviposition (Williamson, 1989).

Kapoor (1993) reported that 0.05% Fenitrothion, 0.05% Malathion, 0.03% Dimethoate and 0.05% Fenthion have been used successfully in minimizing the damage to fruit and vegetables against fruit fly but the use of DDT or BHC is being discouraged now. Sprays with 0.03% Dimethoate and 0.035% Phesalone were very effective against the fruit fly. Fenthion, Dichlorovos, Phosnhamidon and Endosulfan are effectively used for the control of melon fly (Agarlwal *et al.*, 1987).

In field trials in Pakistan in 1985-86, the application of Cypermethrin 10 EC and Malathion 57 EC at 10 days intervals (4 sprays in total) significantly reduced the infestation of *Bactrocera cucurbitae* on Melon (4.8-7.9) compared with untreated control. Malathion was the most effective insecticide (Khan *et al.*, 1992).

Hameed *et al.* (1980) observed that 0.0596 Fenthion, Malathion, Trichlorophos and Fenthion with waiting period of five, seven and nine days respectively was very effective in controlling *Bactrocera cucurbitae* on cucumber in Himachal Pradesh, Various insecticide schedules were tested against *Bactrocera cucurbitae* on pumpkin in Assam during 1997. The most effective treatment in terms of lowest pest incidence and highest yield was carbofuran at 1.5 kg a.i/ha (Borah, 1998).

Nasiruddin and Karim (1992) reviewed that comparatively less fruit fly infestation (8.56%) was recorded in snake gourd sprayed with Dipterex 80 SP compared to those in untreated plot (22.48%). Pawer *et al.* (1984) reported that 0.05% Monocrotophos was very effective in controlling *Bactrocera cucurbitae* in muskmelon.

Rabindranath and Pillai (1986) reported that Synthetic pyrethroids, Permethrin, Fenvelerate, Cypermethrin and Deltamethrin (at 15g a.i/ha) were very useful in controlling *Bactrocera cucurbitae,* in bitter gourd in South India.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at the Agricultural Research Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from December 2016 to March 2017 to study the effectiveness of traps and insecticide for the management of cucurbit fruit fly. The materials and methods that were used for conducting the experiment are presented under the following headings:

3.1 Experimental site

The present experiment was conducted at the Agricultural Research Farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh. The location of the experimental site (plate 1.) is 23°74´N latitude and 90°35´ E longitude and at an elevation of 8.2 m from sea level.

3.2 Climate

The climate is subtropical in nature with moderate temperature and scanty rainfall. The soil of the experimental land belongs to the Madhupur tract and was silty clay in nature having pH ranging from 5.5 to 6.2. Details of the meteorological data during the period of the experiment was collected from the Bangladesh Meteorological Department, Agargoan, Dhaka and presented in Appendix II.

3.3 Characteristics of soil

The soil of the experimental area belongs to the Modhupur Tract under AEZ No. 28. It had shallow red brown terrace soil. The selected plot was medium high land and the soil series was Tejgaon.

3.4 Treatments

The comparative effectiveness of the following 8 treatments against cucurbit fruit fly was evaluated on the basis of reduction of this pest.

T_1 = Bait trap
T_2 = Pheromone trap
T_3 = Insecticide (Voliam flexi 300 SC @ 0.5 ml/L water at 10 days interval)
T_4 = Bait trap + pheromone trap
T_5 = Bait trap + insecticide (Voliam flexi 300 SC @ 0.5 ml/L water at 10 days interval)
T_6 = Pheromone trap + insecticide (Voliam flexi 300 SC @ 0.5 ml/L water at 10 days interval)
T_7 = Bait trap + pheromone trap + insecticide (Voliam flexi 300 SC @ 0.5 ml/L water at 10 days interval)
T_8 = Control

3.5 Design and layout of the experiment

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The unit plot size was 3.0 m × 2.0 m. The distance between plots and blocks was 1.0 m and 1.0 m, respectively.

3.6 Land preparation and fertilization

The experimental plot was ploughed thoroughly by a tractor drawn disc plough followed by harrowing. The land was then labeled prior to transplanting. During land preparation, cow dung was incorporated into the soil at the rate of 5 t/ha. Recommended doses of nutrients comprising N, P, K and S at the rate of 20, 8, 16 and 6 kg/ha were applied.TSP and MP were applied as a basal dose at the time of sowing in all treatments (Fertilizer Recommended Guide, BARC, 2015). The nitrogen in from of urea was applied in 3 equal splits at basal, 30 days after sowing (DAS) and 50 DAS.

3.7 Plant materials

3.7.1 Crop

Cucumber was considered as test crop under the present study. Lal Teer variety was used for the experiment.

3.7.2 Seed source and sowing

The seed of cucumber was collected from Lal Teer seed company, Dhaka. Seeds were sown in the field on 15 December 2016. Five seeds per pit were sown directly. Before sowing the seed was treated with Vitavax 200@ 2 gm/kg of seed. Regular irrigation was done after sowing. Finally three healthy plats were kept in each pit. Damaged and virus infected seed were replaced by new one.

3.8 Collection of trap and insecticides

The bait trap and pheromone trap (plate 5.) was collected from Bangladesh Agriucltural Research Institute (BARI) and Sevin 85 WP were collected from local market to incorporate with bait trap and Voliam flexi 300 SC was also collected from the Savar market for individual use as experimental treatment.

3.9 Cultural practices

After sowing the seeds, a light irrigation was applied to the plots. Subsequent irrigation was done as and when needed. After germination of seedlings soil of each plot was drenched with 1% solution of Vitavax 200 WP to cover the plants from the anthracnose disease. Weeding and drainage facilities were provided as per necessary.

3.10 Preparation of the treatment

3.10.1 Pheromone trap

The rectangular plastic container had around 3-liter capacity and 20-22 cm tall was selected. A triangular hole measuring 10-12 cm height and 10-12 cm base was cut in any two opposite sides. The base of the hole should be 3 cm above the bottom. Water containing two-three drops of detergent should be maintained inside the trap throughout the season. Pheromone soaked cotton or lure was tied inside the trap with thin wire. Fruit fly adults enter the trap and fall into the water and die. Water inside the trap should be replenished often to make sure the trap is not dry. Pheromone dispensers should be continued throughout the cropping season. The pheromone traps should be in the cucurbit field at a distance of 12-15 m starting from first flower initiation and be continued till last harvest.

3.10.2 Bait Trap

This poison bait (plate 4.) was prepared from mashed sweet gourd mixed with water and Sevin 50 WP at the rate of 2.0 g per 100.0 g of mashed sweet gourd. Freshly prepared baits in earthen pots were placed at plant height in cucumber field with the help of bamboo supports. Used baits were changed by freshly prepared baits within 2-3 days to attract more fruit flies.

3.10.3 Voliam flexi 300 SC

Voliam flexi 300 SC was mixed with water before spraying. For this 2.5 ml insecticide was measured by measuring cylinder (pipette). 5.0 L water + 2.5 ml insecticide was mixed in spray tank of a Knapsack sprayer. After proper mixing it was sprayed by knapsack sprayer having a pressure of 4.5 kg/cm^{-2} .

3.10.4 Untreated control

The plots under the untreated control were left without any control measures. All other intercultural operations were similar to those of other treatments.

3.11 Data collection and analysis

The whole reproductive period of cucumber was divided into three stage *viz*., early, mid and late fruiting stages. From flower initiation to 20 days was treated as early fruiting stage, 20 - 40 days as mid fruiting stage and after 40 day to end of the final harvest was considered as late fruiting stage. The effectiveness of each treatment was evaluated on the basic of some pre-selected parameters.

The following parameters were considered during data collection at each stage of plant growth.

1. Number of captured insects per plant or plot,
2. Number of infested fruits (plate 1. & 7.) per plot,
3. Number of healthy fruits (plate 6.) per plot,
4. Weight of healthy fruits
5. Weight of infested fruits,
6. Healthy fruit yield per plot
7. Infested fruit yield per plot
8. Yield

3.11.1 Percent fruit infestation by number

After harvesting, the healthy fruits (HF) and the infested fruits (IF) were separated by visual observation. The number of healthy fruits (HF) and the infested fruits (IF) of early, mid and late fruiting stages were counted and the percent fruit infestation for each treatment was calculated by using the following formula:

$$\text{Fruit infestation (\%) by number} = \frac{IF}{HF + IF} \times 100$$

Where, IF = Number of infested fruits
HF = Number of healthy fruits

3.11.2 Percent fruit infestation by weight

After sorting of healthy fruits (HF) and the infested fruits (IF), the weight was taken for healthy infested and total one separately. The percent infested fruit by weight for each treatment was calculated by using the following formula:

$$\text{Fruit infestation (\%) by weight} = \frac{IF}{HF + IF} \times 100$$

Where, IF = Weight of infested fruits
HF = Weight of healthy fruits

3.11.3 Fruit yield

After harvesting, the weight of healthy and infested fruits were separated and recorded the total yield under each treatment and finally converted to determine the yield (t/ha). The percent increase and decrease of yield over control was computed by using the following formula:

$$\text{Increase of yield (\%) over control} = \frac{\text{Yield of treated plot} - \text{Yield of control plot}}{\text{Yield of control plot}} \times 100$$

$$\text{Decrease of yield (\%) over control} = \frac{\text{Yield of control plot} - \text{Yield of treated plot}}{\text{Yield of control plot}} \times 100$$

3.12 Statistical analyses

The data on different parameters as well as yield of country bean were statistically analyzed to find out the significant differences among the effects of different treatments. The mean values of all the characters were calculated and analyses of variance were performed by the 'F' (variance ratio) test. The significance of the differences among the mean values of treatment in respect of different parameters was estimated by the Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

Plate 1: Infested fruit

Plate 2: Raising seedlings

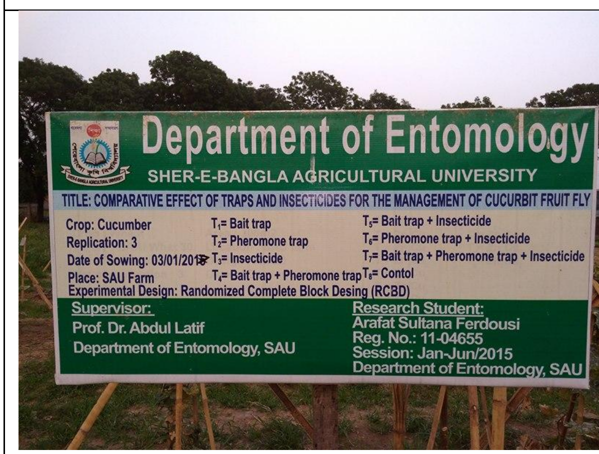

Plate 3: Experimental site

Plate 4: Bait trap

Plate 5: Bait trap and Pheromonat trap

Plate 6: Healthy cucumber

	
Plate 7: Infested fruits	Plate 8: Cucumber plant
	
Plate 9: A plant with fruit and flower	Plate 10: A vine with flower

CHAPTER IV

RESULTS AND DISCUSSIN

The experiment on the study of effectiveness of traps and insecticides on the incidence and management of cucurbit fruit fly in cucumber was conducted during December 2016 to March 2017 at the experimental farm of Sher-e- Bangla Agricultural University (SAU), Dhaka. The results have been presented and discussed under the following headings and sub-headings:

4.1 Effect of different treatments on production of healthy fruits of cucumber and fruit infestation by number

4.1.1 Early fruiting stage

The number of healthy, infested and total fruits of cucumber per plant at early fruiting stage was significantly varied in different treatments (Table 1). The highest number of healthy fruits/plant (10.3) was harvested from T_7 (bait trap + pheromone trap + Voliam flexi 300 SC), which significantly different from others, followed by (7.33) in T_5 (bait trap + Voliam flexi 300 SC). But the lowest number of healthy fruits/plant (2.33) was harvested from T_8 (control) which significantly different from others. No significant variation was observed between T_3 (6.00) and T_6 (6.00) and between T_1 (4.67) and T_2 (4.33) in terms of production of healthy fruits per plant, followed by T_2 (pheromone trap) and T_1 (bait trap) which were significantly different from other but significantly same with each other.

The data on number of infested fruits/plant at early fruiting stage have shown in Table 1. It was found that the lowest number of infested fruits/plant (1.00) was harvested from T_7 (bait trap + pheromone trap + Voliam flexi 300 SC) treatment which statistically identically with T_5 (bait trap + Voliam flexi 300 SC) and T_6 (pheromone trap + Voliam flexi 300 SC). The highest number of infested fruits/plant (4.33) was harvested from T_8 (Control) treatment which significantly different from other treatments.

Similarly, the lowest level of infestation (8.83%) by number at early fruiting stage was recorded from T_7 (bait trap + pheromone trap + Voliam flexi 300 SC) followed by T_5 (bait trap + Voliam flexi 300 SC) and T_6 (pheromone trap + Voliam flexi 300 SC) which significantly similar with each other. Conversely, the highest infestation (65.02%) was recorded from T_8 (Control) plot which significantly different from others.

Table 1. Number of healthy, infested and total fruits per plant and percent fruit infestation by cucurbit fruit fly at early fruiting stage.

Treatments	Number of fruits plant^{-1}			Percent fruit infestation by number
	Healthy	Infested	Total	
T_1	4.67 e	2.67 c	7.34 e	36.38 d
T_2	4.33 e	3.33 b	7.66 d	43.47 b
T_3	6.00 c	2.00 d	8.00 c	25.00 e
T_4	5.33 d	3.33 b	8.66 b	38.45 c
T_5	7.33 b	1.33 e	8.66 b	15.36 fg
T_6	6.00 c	1.33 e	7.33 e	18.14 f
T_7	10.30 a	1.00 e	11.3 a	8.83 h
T_8	2.33 f	4.33 a	6.66 f	65.02 a
$LSD_{0.05}$	**0.524**	**0.415**	**0.307**	**2.716**
CV (%)	**7.738**	**4.226**	**6.514**	**8.392**

Means followed by the same letter(s) in a column are not significantly different at 5% level of probability by DMRT.

T_1 = Bait trap, T_2 = Pheromone trap, T_3 = Insecticide, T_4 = Bait trap + pheromone trap, T_5 = Bait trap + insecticide, T_6 = Pheromone trap + insecticide, T_7 = Bait trap + pheromone trap + insecticide, T_8 = Control

Considering percent reduction over control (Figure 1.), the highest infestation (86.43%) was achieved from T_7 (bait trap + pheromone trap + Voliam flexi 300 SC) followed by T_5 (bait trap + Voliam flexi 300 SC) while the lowest (33.14%) from T_2 (Pheromone trap) followed by T_1 (bait trap).

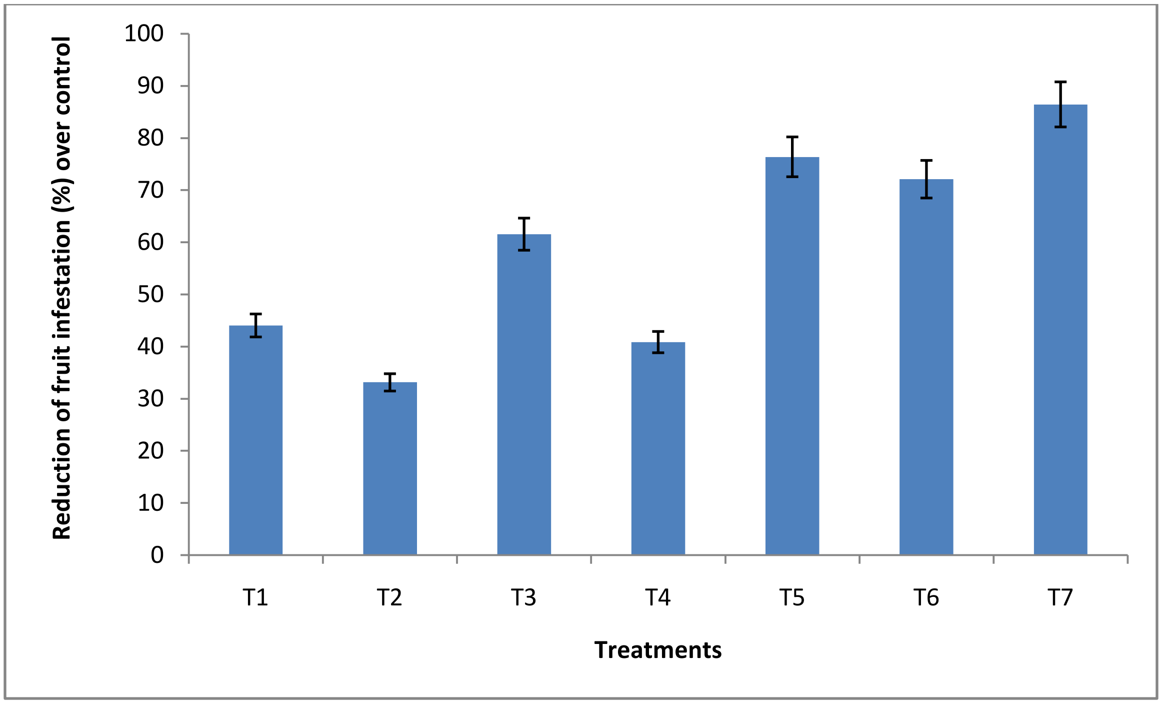

Figure 1. Percent reduction of fruit infestation over control by number at early fruiting stage. Beam on top of the bar indicates standard deviation.

T_1 = Bait trap, T_2 = Pheromone trap, T_3 = Insecticide, T_4 = Bait trap + pheromone trap, T_5 = Bait trap + insecticide, T_6 = Pheromone trap + insecticide, T_7 = Bait trap + pheromone trap + insecticide, T_8 = Control

4.1.2 Mid fruiting stage

Significant influence was observed among the different treatments resulted on healthy and infested fruits/plant against cucurbit fruit fly at mid fruiting stage (Table 2.). The highest number (10.0) of healthy fruits/plant at mid fruiting stage was harvested from T_7 (bait trap + pheromone trap + Voliam flexi 300 SC), which significantly different from others, followed by T_5 (bait trap + insecticide) (8.67) whereas the lowest number of healthy fruits/plant (3.33) was harvested from T_8 (control) at mid fruiting stage which also significantly different from others. No significant variation was observed in T_1 (5.33) and T_2 (5.33) in terms of production of healthy fruits per plant.

The data on number of infested fruits/plant at early fruiting stage have shown in Table 2. It was found that the lowest number of infested fruits/plant (1.33) was observed in T_7 (bait trap + pheromone trap + Voliam flexi 300 SC), which statistically similar with T_3 (Voliam flexi 300 SC) and T_4 (bait trap + pheromone trap). But the highest number of infested fruits/plant (4.00) was harvested from T_8 (control) which significantly different from other treatments.

Similarly, the lowest level of infestation (11.74%) by number at mid fruiting stage was recorded from T_7 (Bait trap + pheromone trap + Voliam flexi 300 SC), which significantly different from others. Treatment T_4 (bait trap + pheromone trap) and T_6 (pheromone trap + Voliam flexi 300 SC) which was significantly similar with each other. The highest level of infestation (54.57%) was identified from T_8 (control) plot which was significantly different from other, followed by T_2 (pheromone trap).

Table 2. Number of healthy, infested and total fruits per plant and percent fruit infestation by cucurbit fruit fly at mid fruiting stage.

Treatments	Number of fruits plant^{-1}			Percent fruit infestation by number
	Healthy	Infested	Total	
T_1	5.33 f	2.67 c	8.00 f	33.38 bc
T_2	5.33 f	3.00 b	8.33 e	36.01 b
T_3	7.33 d	1.33 f	8.66 d	15.36 f
T_4	6.33 e	1.33 f	7.66 g	17.36 de
T_5	8.67 b	2.33 d	11.00 b	21.18 d
T_6	8.00 c	1.67 e	9.67 c	17.27 de
T_7	10.0 a	1.33 f	11.33 a	11.74 g
T_8	3.33 g	4.00 a	7.33 h	54.57 a
$LSD_{0.05}$	**0.276**	**0.263**	**0.291**	**2.617**
CV (%)	**6.794**	**4.225**	**8.329**	**8.536**

Means followed by the same letter(s) in a column are not significantly different at 5% level of probability by DMRT.

T_1 = Bait trap, T_2 = Pheromone trap, T_3 = Insecticide, T_4 = Bait trap + pheromone trap, T_5 = Bait trap + insecticide, T_6 = Pheromone trap + insecticide, T_7 = Bait trap + pheromone trap + insecticide, T_8 = Control

Considering percent reduction over control (Figure 2.), the highest (78.49%) was achieved from T_7 (bait trap + pheromone trap + Voliam flexi 300 SC) followed by T_5 (Bait trap + Voliam flexi 300 SC) whereas the lowest (34.00%) obtained from T_4 (bait trap + pheromone trap).

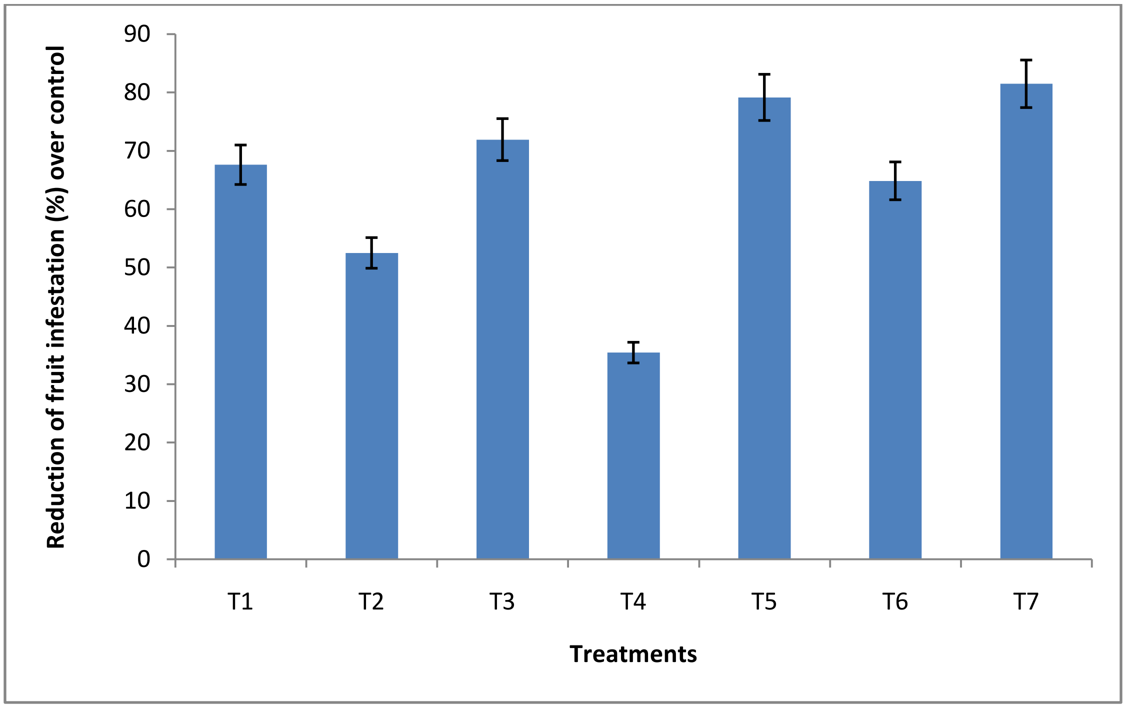

Figure 2. Percent reduction over control by number at mid fruiting stage. Beam on top of the bar indicate standard deviation.

T_1 = Bait trap, T_2 = Pheromone trap, T_3 = Insecticide, T_4 = Bait trap + pheromone trap, T_5 = Bait trap + insecticide, T_6 = Pheromone trap + insecticide, T_7 = Bait trap + pheromone trap + insecticide, T_8 = Control

4.1.3 Late fruiting stag

The number of healthy, infested and total fruits of cucumber per plant at early fruiting stage was significantly varied in different treatments (Table 3.). Among the treatments, the highest (8.67) number of healthy fruits/plant was harvested from T_7 (bait trap + pheromone trap+ Voliam flexi 300 SC), which significantly different from others. But the lowest number of healthy fruits/plant (1.67) was recorded from T_8 (control) which significantly different from others.

It was found that the lowest number of infested fruits/plant (1.00) was harvested from T_7 (bait trap + pheromone trap + Voliam flexi 300 SC) treatment which was statistically different from others. The highest number of infested fruits/plant (4.67) was harvested from T_8 (Control) which was significantly different from other treatments, followed by $T_{4.}$

Similarly, the lowest level of infestation (13.64%) by number at late fruiting stage was recorded from T_7 (Bait trap + pheromone trap + Voliam flexi 300 SC). Nonetheless, the highest infestation (73.66%) was identified from T_8 (Control) plot which significantly different from other.

Table 3. Number of healthy, infested and total fruits per plant and percent fruit infestation by cucurbit fruit fly at late fruiting stage.

Treatments	Number of fruits plant^{-1}			Percent infestation by number
	Healthy	Infested	Total	
T_1	5.33 e	1.67 e	7.00 e	23.86 de
T_2	4.33 f	2.33 c	6.66 f	34.98 c
T_3	6.33 d	2.00 d	8.33 d	20.68 f
T_4	3.67 g	3.33 b	7.00e	47.57 b
T_5	7.33 b	1.33 f	8.66 c	15.36 gh
T_6	6.67 c	2.33 c	9.00 b	25.89 d
T_7	8.67 a	1.00 g	9.67 a	13.64 h
T_8	1.67 h	4.67 a	6.34 g	73.66 a
$LSD_{0.05}$	**0.278**	**0.251**	**0.294**	**2.137**
CV (%)	**4.819**	**3.224**	**5.506**	**6.113**

Means followed by the same letter(s) in a column are not significantly different at 5% level of probability by DMRT.

T_1 = Bait trap, T_2 = Pheromone trap, T_3 = Insecticide, T_4 = Bait trap + pheromone trap, T_5 = Bait trap + insecticide, T_6 = Pheromone trap + insecticide, T_7 = Bait trap + pheromone trap + insecticide, T_8 = Control

Considering percent reduction over control (Figure 3), the highest (81.48%) was achieved from T_7 (bait trap + pheromone trap + Voliam flexi 300 SC) followed by T_5 (Bait trap ++ Voliam flexi 300 SC) while the lowest (35.42%) from T_4 (bait trap + pheromone trap) followed by T_2 (pheromone trap).

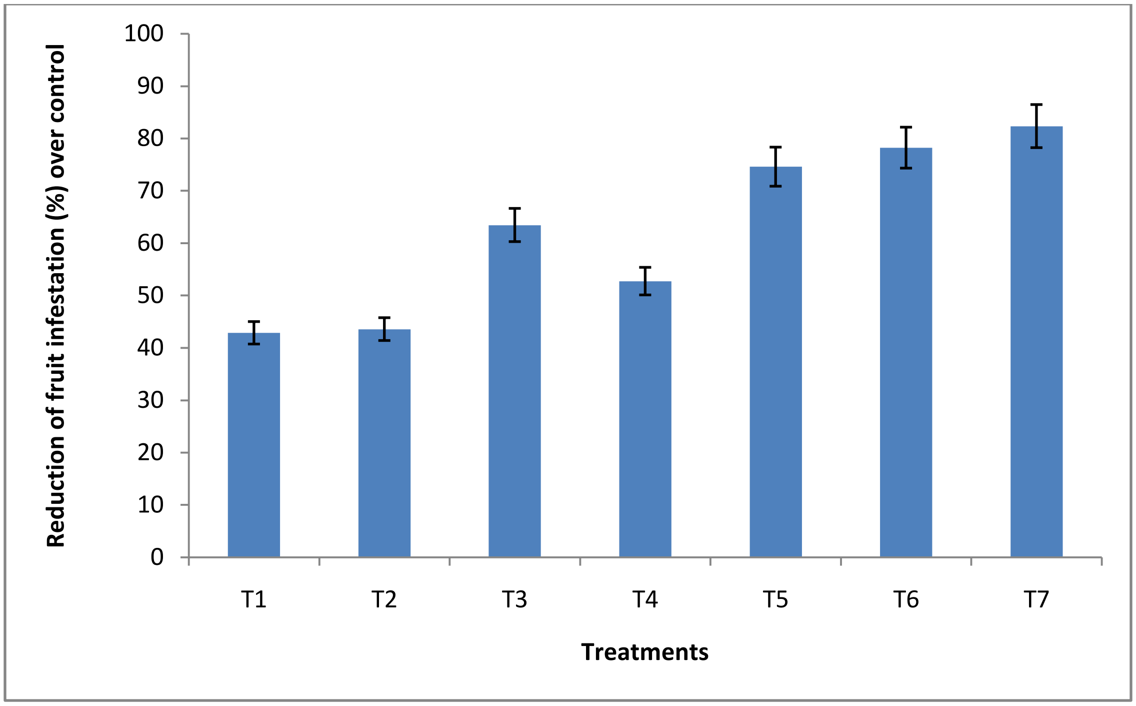

Figure 3. Percent reduction over control by number at late fruiting stage.Beam on top of the bar indicate standard deviation.

T_1 = Bait trap, T_2 = Pheromone trap, T_3 = Insecticide, T_4 = Bait trap + pheromone trap, T_5 = Bait trap + insecticide, T_6 = Pheromone trap + insecticide, T_7 = Bait trap + pheromone trap + insecticide, T_8 = Control

4.2 Effect of different treatments on healthy and infested fruits by weight

4.2.1 Early fruiting stage

The effect of different treatments on the weight of healthy fruits/plant at early fruiting stage of cucumber was significant which has been shown in (Table 4). Among the treatments, T_7 (bait trap + pheromone trap + Volium flexi) produced the highest healthy fruits/plant (895.33 g) which significantly different from others, followed by 624.33 in T_5 (bait trap + Volium flexi). But the lowest healthy fruits/plant (204.33 g) was harvested from T_8 (control) which was significantly different from others.

Table 4. Effects of different treatments against cucurbit fruit fly on cucumber infestation by weight at early fruiting stage

Treatments	Weight of fruits $plant^{-1}$ (g)			Percent infestation by weight
	Healthy	Infested	Total	
T_1	431.47 f	269.33 b	700.80 d	38.43 b
T_2	382.83 g	234.17 c	617.00 f	37.95 b
T_3	557.33 d	181.67 e	739.00 c	24.58 d
T_4	476.33 e	222.00 d	698.33 d	31.79 c
T_5	624.33 b	128.67 f	753.00 b	17.09 e
T_6	586.67 c	100.67 h	687.34 e	14.65 ef
T_7	895.33 a	120.67 g	1016.0 a	11.88 f
T_8	204.33 h	419.67 a	624.00 g	67.25 a
$LSD_{0.05}$	**3.294**	**2.117**	**4.736**	**2.418**
CV (%)	**11.361**	**9.527**	**12.442**	**8.638**

Means followed by the same letter(s) in a column are not significantly different at 5% level of probability by DMRT.

T_1 = Bait trap, T_2 = Pheromone trap, T_3 = Insecticide, T_4 = Bait trap + pheromone trap, T_5 = Bait trap + insecticide, T_6 = Pheromone trap + insecticide, T_7 = Bait trap + pheromone trap + insecticide, T_8 = Control

The data on weight of infested fruits/plant at early fruiting stage have shown in Table 4. It was found that the lowest weight of infested fruits/plant (100.67g) was recorded from T_6 (pheromone trap + Voliam flexi 300 SC) treatment which statistically identically with T_5 (bait trap + Voliam flexi 300 SC) and T_7 (bait trap + pheromone trap + Voliam flexi 300 SC). The highest infested fruits/plant (419.67 g) was recorded from T_8 (control) which significantly different from other treatments.

Similarly, the lowest level of infestation (11.88%) by weight at early fruiting stage was recorded from T_7 (Bait trap + pheromone trap + Voliam flexi 300 SC) followed by T_5 (bait trap + Voliam flexi 300 SC) and T_6 (pheromone trap +

Voliam flexi 300 SC) which was significantly similar with each other. Moreover, the highest level of infestation (67.25%) was identified from T_8 (control) plot which was significantly different from others, followed by T_1 (bait trap) and T_2 (pheromone trap).

Considering percent reduction over control (Figure 4), the highest (82.34%) was achieved from T_7 (bait trap + pheromone trap + Volium flexi) followed by T_6 (pheromone trap + Volium flexi) where the lowest (42.86%) was obtained from T_1 (bait trap) followed by T_2 (pheromone trap).

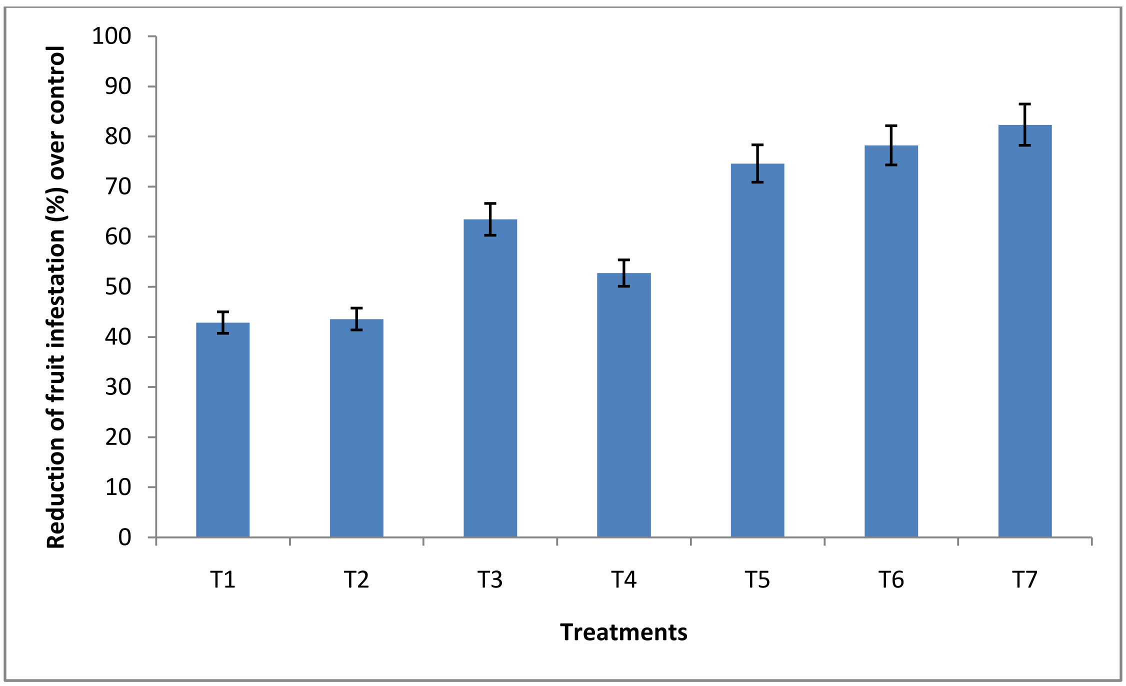

Figure 4. Percent reduction over control by weight at early fruiting stage. Beam on top of the bar indicate standard deviation.

T_1 = Bait trap, T_2 = Pheromone trap, T_3 = Insecticide, T_4 = Bait trap + pheromone trap, T_5 = Bait trap + insecticide, T_6 = Pheromone trap + insecticide, T_7 = Bait trap + pheromone trap + insecticide, T_8 = Control

4.2.2 Mid fruiting stage

Significant influence was observed among the different treatments on weight of healthy and infested fruits/plant against cucurbit fruit fly at mid fruiting stage (Table 5). The highest weight of healthy fruits/plant (1050.0 g) at mid fruiting stage was harvested from T_7 (bait trap + pheromone trap + Voliam flexi 300 SC), which significantly different from others, followed by T_6 (pheromone trap + Voliam flexi 300 SC) while the lowest weight of healthy fruits/plant (347.33 g) from T_8 (control) at mid fruiting stage which also significantly different from others.

Table 5. Effect of different treatments against cucurbit fruit fly against infestation by weight at mid fruiting stage

Treatments	Weight of fruits plant^{-1} (g)			Percent infestation by weight
	Healthy	Infested	Total	
T_1	573.00 f	277.67 c	850.67 f	32.64 c
T_2	690.00 e	122.33 g	812.33 g	15.06 e
T_3	749.33 d	138.67 f	888.00 d	15.62 e
T_4	551.33 g	309.00 b	860.33 e	35.92 b
T_5	814.33 c	183.00 e	997.33 c	18.35 d
T_6	890.33 b	235.67 d	1126.0 b	20.93 c
T_7	1050.0 a	121.67 g	1171.7 a	10.38 f
T_8	347.33 h	511.67 a	859.00 e	59.57 a
$LSD_{0.05}$	**4.894**	**3.296**	**5.012**	**1.206**
CV (%)	**10.574**	**8.322**	**12.627**	**7.533**

Means followed by the same letter(s) in a column are not significantly different at 5% level of probability by DMRT.

T_1 = Bait trap, T_2 = Pheromone trap, T_3 = Insecticide, T_4 = Bait trap + pheromone trap, T_5 = Bait trap + insecticide, T_6 = Pheromone trap + insecticide, T_7 = Bait trap + pheromone trap + insecticide, T_8 = Control

The data on weight of infested fruits/plant at mid fruiting stage have shown in Table 5. It was found that the lowest weight of infested fruits/plant (121.67 g) was harvested from T_7 (bait trap + pheromone trap + Voliam flexi 300 SC) treatment whereas the highest infested fruits/plant (511.67 g) was observed from T_8 (control) which significantly different from other treatments.

Similarly, the lowest percent infestation by weight (10.38%) at mid fruiting stage was recorded from T_7 (bait trap + pheromone trap + Voliam flexi 300 SC). Conversely, the highest level of infestation (59.57%) was identified from T_8 (control) plot which was significantly different from others, followed by T_4 (bait trap + pheromone trap).

Considering percent reduction over control (Figure 5), the highest result (82.57%) was achieved from T_7 (bait trap + pheromone trap + Voliam flexi 300 SC) followed by T_2 (Pheromone trap) and T_3 (Voliam flexi 300 SC) where the lowest (39.71%) from T_4 (bait trap + pheromone trap).

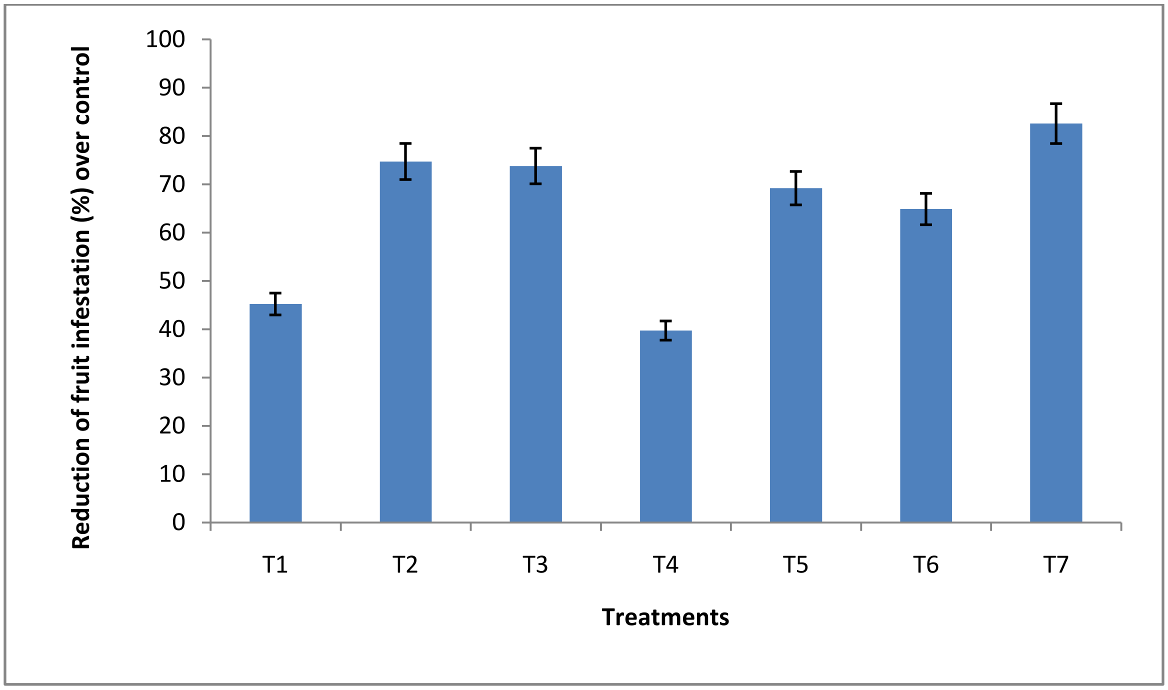

Figure 5. Percent reduction over control by weight at mid fruiting stage. Beam on top of the bar indicate standard deviation.

T_1 = Bait trap, T_2 = Pheromone trap, T_3 = Insecticide, T_4 = Bait trap + pheromone trap, T_5 = Bait trap + insecticide, T_6 = Pheromone trap + insecticide, T_7 = Bait trap + pheromone trap + insecticide, T_8 = Control

4.2.3 Late fruiting stage

Healthy and infested fruits achievement by weight under different treatments against cucurbit fruit fly was significant at late fruiting stage (Table 6).

The highest weight of healthy fruits/plant (870.67 g) was collected from T_5 (Bait trap + Voliam flexi 300 SC) at late fruiting stage, which significantly different from others, followed by (790.00 g) in T_7 (bait trap + pheromone trap + Voliam flexi 300 SC), where the lowest healthy fruits/plant (229.33 g) was harvested from T_8 (control) at late fruiting stage which also significantly different from other treatments.

Table 6: Effect of different treatments against cucurbit fruit fly against infestation by weight at late fruiting stage

Treatments	Weight of fruits plant^{-1} (g)			Percent infestation by weight
	Healthy	Infested	Total	
T_1	533.33 f	265.33 d	798.66 e	33.22 c
T_2	613.00 d	179.67 f	792.67 f	22.67 e
T_3	602.00 e	147.00 g	749.00 g	19.63 e
T_4	478.33 g	350.67 b	829.00 d	42.30 b
T_5	870.67 a	117.67 h	988.34 c	11.91 f
T_6	724.00 c	277.67 c	1001.7 a	27.72 d
T_7	790.00 b	204.00 e	994.00 b	20.52 e
T_8	229.33 h	453.33 a	682.66 h	66.41 a
$LSD_{0.05}$	**3.876**	**3.241**	**4.077**	**2.851**
CV (%)	**8.594**	**8.376**	**11.537**	**7.448**

Means followed by the same letter(s) in a column are not significantly different at 5% level of probability by DMRT.

T_1 = Bait trap, T_2 = Pheromone trap, T_3 = Insecticide, T_4 = Bait trap + pheromone trap, T_5 = Bait trap + insecticide, T_6 = Pheromone trap + insecticide, T_7 = Bait trap + pheromone trap + insecticide, T_8 = Control

The data on weight of infested fruits/plant at late fruiting stage have shown in Table 6. It was found that the lowest weight of infested fruits/plant (117.67 g) was recorded from T_5 (bait trap + Voliam flexi 300 SC) treatment where the highest infested fruits/plant (453.33 g) from T_8 (control) which significantly different from other treatments.

Similarly, the lowest percent infestation was recorded by weight (11.91%) at late fruiting stage was recorded from T_5 (bait trap + Voliam flexi 300 SC). However, the highest infestation (66.41%) was identified from T_8 (control) which significantly different from others, followed by in T_4 (42.30).

Considering percent reduction over control (Figure 6), the highest (82.07%) was achieved from T_5 (bait trap + Voliam flexi 300 SC) followed by T_3 (Voliam flexi 300 SC) and T_7 (bait trap + pheromone trap + Voliam flexi 300 SC) while the lowest (35.42%) from T_4 (bait trap + pheromone trap).

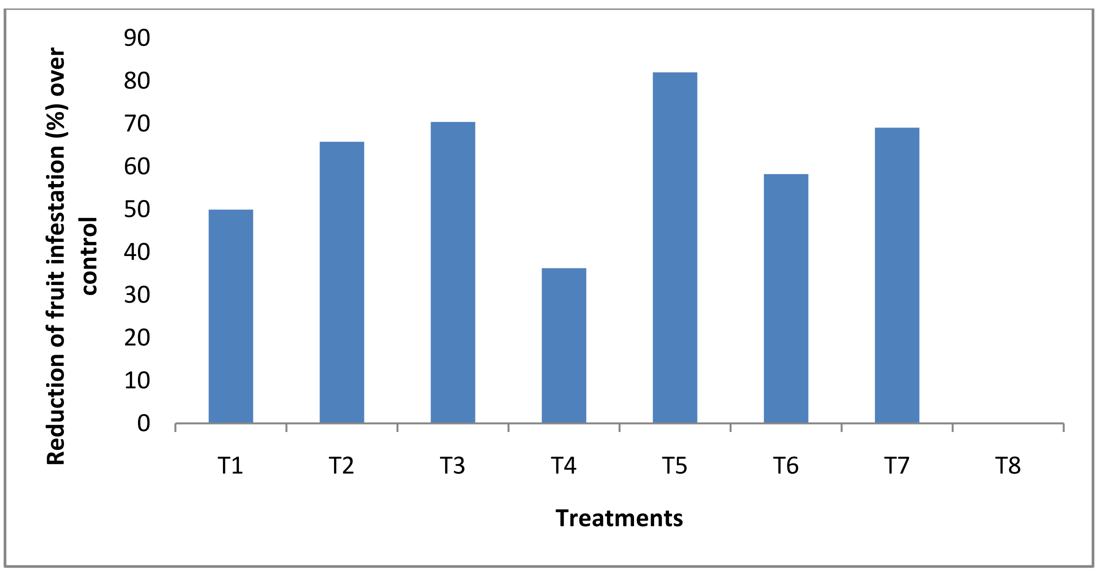

Figure 6. Percent reduction over control by weight at late fruiting stage. Beam on top of the bar indicate standard deviation.

T_1 = Bait trap, T_2 = Pheromone trap, T_3 = Insecticide, T_4 = Bait trap + pheromone trap, T_5 = Bait trap + insecticide, T_6 = Pheromone trap + insecticide, T_7 = Bait trap + pheromone trap + insecticide, T_8 = Control

4.3 Effect of different treatment on yield performance of cucumber

Data on yield performance showed significant variation among the treatments (Table 7). Results indicated that the highest yield of healthy fruit (18.24 t ha^{-1}) was obtained from T_7 (bait trap + pheromone trap + Voliam flexi 300 SC) treatment followed by T_5 (bait trap + Voliam flexi 300 SC) but the lowest (5.21 t ha^{-1}) from T_8 (control) treatment. Conversely, the lowest infested fruit yield (2.98 t ha^{-1}) was found from T_7 (bait trap + pheromone trap + Voliam flexi 300 SC) where the highest (9.23 t ha^{-1}) from T_8 (control) treatment. Accordingly, the highest total fruit yield (21.21 t ha^{-1}) was obtained from T_7 (bait trap + pheromone trap + Voliam flexi 300 SC) treatment but the lowest (14.44 t ha^{-1}) from T_8 (control) treatment.

In terms of percent increase of yield over control, the highest (250.10%) was achieved from T_7 (bait trap + pheromone trap + Voliam flexi 300 SC) whereas the lowest (86.95%) from T_4 (bait trap + pheromone trap). Similarly, considering percent decrease of infested fruits over control, the highest (70.96%) was found from T_7 (bait trap + pheromone trap + Voliam flexi 300 SC) but the lowest (32.94%) from T_4 (bait trap + pheromone trap).

Regarding percent increase of total fruit yield over control, the highest (46.95%) was found from T_7 (bait trap + pheromone trap + Voliam flexi 300 SC) while the lowest (10.30%) from T_4 (bait trap + pheromone trap) and T_3 (Voliam flexi 300 SC).

Similar results was observed on yield parameters of cucumber for controlling fruit fly using different methods viz. bait trap, pheromone trap and insecticide and also IPM package by Bharadiya and Bhut (2017), Oke and Sinon (2013), Nasiruddin and Karim (1992), Akhtaruzzaman *et al.* (2000), Yubak (2001), Sapkota *et al.* (2010), Rakshit *et al.* (2011) and Akram *et al*. (2010).

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 but control treatment showed the lowest performance. Nasiruddin and Karim (1992) reported that bait spray (1.0 g Dipterex 80 SP and 100 g of molasses per liter of water) on snake gourd against fruit fly *(Bactrocera cucurbitae)* showed 8.50% infestation compared to 22.48% in control. Bharadiya and Bhut (2017), Oke and Sinon (2013) and Kapoor (1993) also reported that chemical insecticide significantly decrease fruit fly presence and infestation of crops.

Table 7. Effect of different treatments against cucurbit fruit fly on yield ha^{-1} of cucumber

Treatments	**Fruit yield ha^{-1} (t)**				**Total fruit yield (t ha^{-1})**	**Percent increase over control**
	Healthy fruit yield (t ha^{-1})	**Percent increase over control**	**Infested fruit yield (t ha^{-1})**	**Percent decrease over control**		
T_1	9.93 f	90.60	5.18 c	43.88	15.11 f	4.64
T_2	11.86 e	127.64	3.49 e	62.19	15.35 f	6.30
T_3	13.17 d	152.78	2.75 g	70.10	15.93 d	10.32
T_4	9.74 f	86.95	6.19 b	32.94	15.92 d	10.30
T_5	15.14 b	190.60	2.68 g	67.71	17.82 c	23.41
T_6	14.48 c	177.93	4.63 d	49.84	19.11 b	32.34
T_7	18.24 a	250.10	2.98 f	70.96	21.22 a	46.95
T_8	5.21 g	--	9.23 a	--	14.44 g	--
$LSD_{0.05}$	**0.214**	**--**	**0.207**	**--**	**0.317**	**--**
CV (%)	**7.886**	**--**	**5.219**	**--**	**6.374**	**--**

Means followed by the same letter(s) in a column are not significantly different at 5% level of probability by DMRT.

T_1 = Bait trap, T_2 = Pheromone trap, T_3 = Insecticide, T_4 = Bait trap + pheromone trap, T_5 = Bait trap + insecticide, T_6 = Pheromone trap + insecticide, T_7 = Bait trap + pheromone trap + insecticide, T_8 = Control

4.4 Incidence of cucurbit fruit fly captured by different traps

Data presented in Table 8 showed significant variation on presence of cucurbit fruit fly plot^{-1} captured by different trap. It was observed that T_4 (bait trap + pheromone trap) treatment showed highest incidence (7.00) of fruit fly which statistically identical with T_1 (bait trap) where the lowest was found from T_7 (bait trap + pheromone trap+ Voliam flexi 300 SC) followed by T_5 (bait trap + Voliam flexi 300 SC) and T_6 (pheromone trap + Voliam flexi 300 SC). But the lowest incidence in T_7 (bait trap + pheromone trap + Voliam flexi 300 SC), T_6 (pheromone trap + Voliam flexi 300 SC) and T_5 (bait trap + Voliam flexi 300 SC) might be due to cause of lower presence in the plot on account of insecticide spray.

Table 8. Incidence of cucurbit fruit fly plot^{-1} by number at different growing season of cucumber captured by different traps

Treatments	Incidence of cucurbit fruit fly at			
	Early fruiting stage	Mid fruiting stage	Late fruiting stage	Total
T_1	1.25 b	2.50 a	2.75 b	6.50 a
T_2	1.00 c	2.25 b	2.25 c	5.50 b
T_3	--	--	--	--
T_4	1.50 a	2.50 a	3.00 a	7.00 a
T_5	0.75 d	1.50 d	1.25 e	3.50 c
T_6	0.80 d	1.75 c	1.50 d	4.05 c
T_7	0.25 e	1.25 e	1.00 f	2.50 d
T_8	--	--	--	--
$LSD_{0.05}$	**0.114**	**0.107**	**0.136**	**0.517**
CV (%)	**3.216**	**6.319**	**4.226**	**7.065**

Means followed by the same letter(s) in a column are not significantly different at 5% level of probability by DMRT.

T_1 = Bait trap, T_2 = Pheromone trap, T_3 = Insecticide, T_4 = Bait trap + pheromone trap, T_5 = Bait trap + insecticide, T_6 = Pheromone trap + insecticide, T_7 = Bait trap + pheromone trap + insecticide, T_8 = Control

4.5 Correlation between incidence of cucurbit fruit fly and healthy fruit yield/plant at different fruiting stage

Incidence of cucurbit fruit fly significantly decreased healthy fruit weight/plant with the increasing of cucurbit fruit fly population at early fruiting stage (Figure 7), mid fruiting stage (Figure 8) and late fruiting stage (Figure 9). At all fruiting stage (early, mid and late), it was found that healthy fruit yield/plant was negatively correlated with incidence of cucurbit fruit fly. At early fruiting stage the correlation equation was y = -0.002x + 2.057 with the R^2 value of 0.729. Similarly, at mid and late stage the correlation equation was y = -0.002x + 3.958 and y= 0.005x + 5.444 respectively and R^2 value was 0.905 and 0.923, respectively.

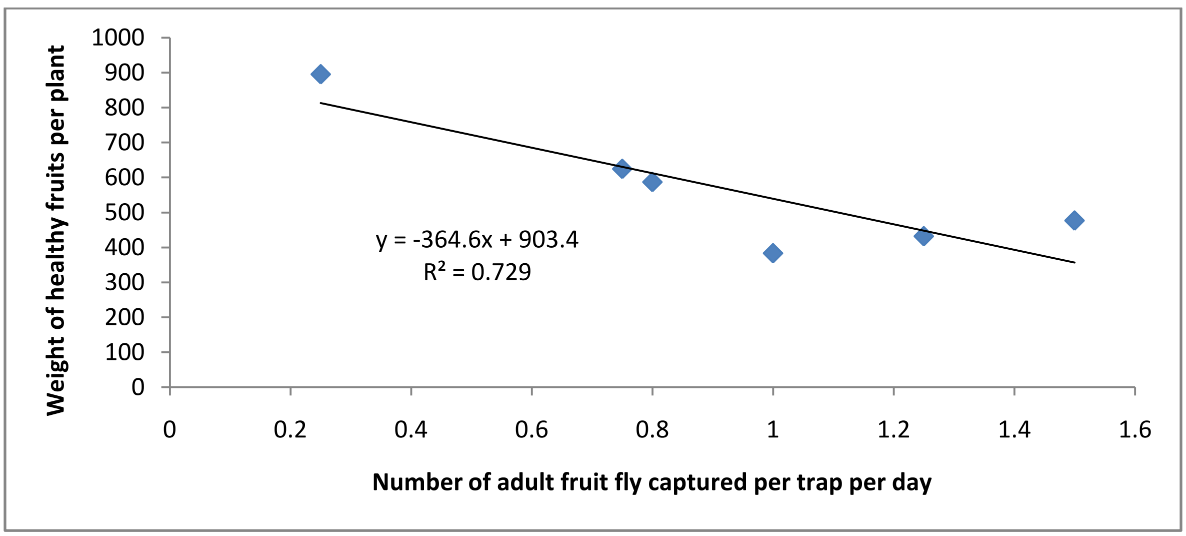

Figure 7. Relationship between number of adult fruit fly caught per trap per day and healthy fruit weight per plant at early fruiting stage.

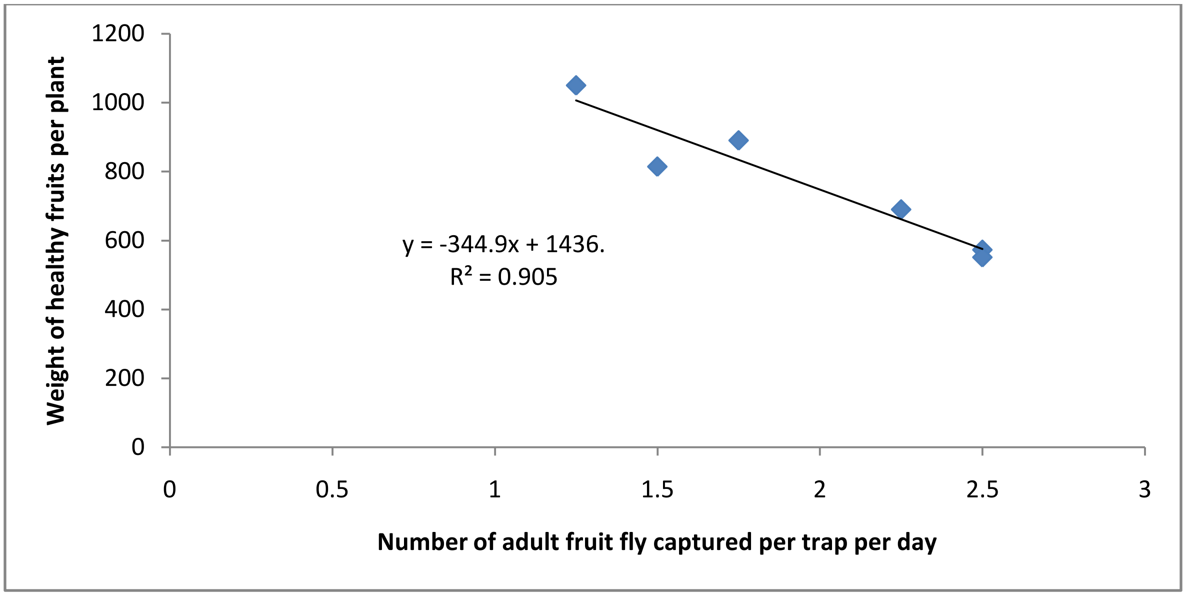

Figure 8. Relationship between number of adult fruit fly caught per trap per day and healthy fruit weight per plant at mid fruiting stage.

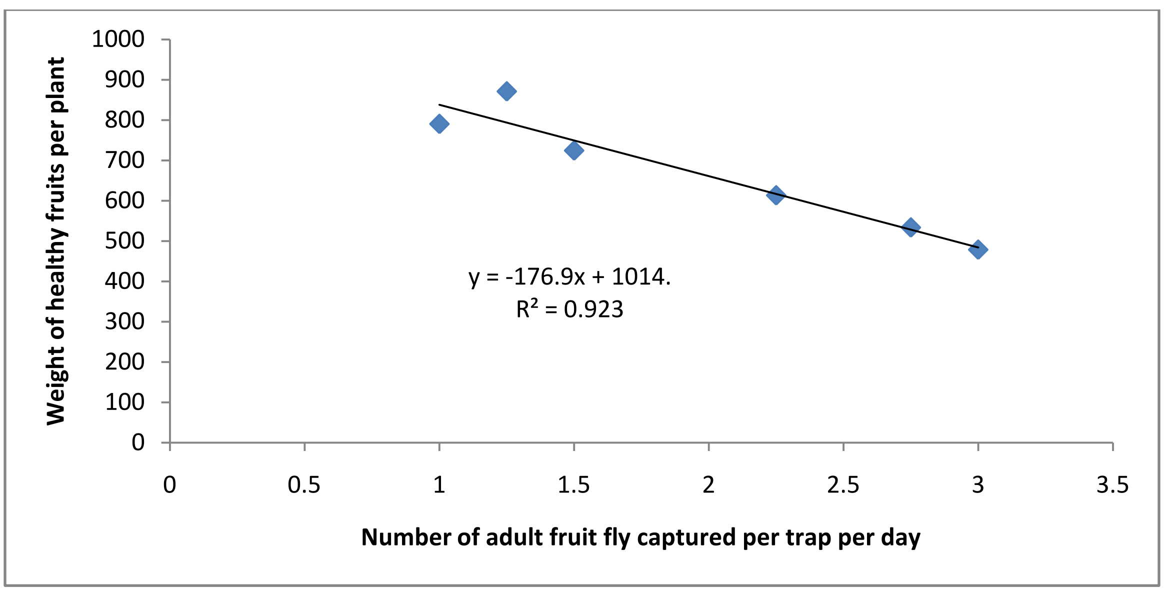

Figure 9. Relationship between number of adult fruit fly caught per trap per day and healthy fruit weight per plant at late fruiting stage.

CHAPTER V

SUMMARY AND CONCLUSION

A field experiment was conducted at Sher-e-Bangla Agriculture University farm to find out the comparative effect of traps and insecticides for the management of cucurbit fruit fly, *Bactrocera cucurbitae* on cucumber during December 2016 to March 2017. The treatments of the experiment were T_1 (bait trap), T_2 (pheromone trap), T_3 (Voliam flexi 300 SC), T_4 (bait trap + pheromone trap), T_5 (bait trap + Voliam flexi 300 SC), T_6 (Pheromone trap + Voliam flexi 300 SC), T_7 (bait trap + pheromone trap + Voliam flexi 300 SC) and T_8 (Control). Voliam flexi 300 SC @ 0.50 ml/liter water was used as chemical insecticide. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The whole reproductive period of cucumber was divided into three stages *viz*., early, mid and late fruiting stage. Data were collected on number of healthy, infested and total fruits/plant and weight of healthy, infested and total fruits/plant at early, mid and late fruiting stage of cucumber.

The highest number of healthy fruits plant^{-1} (10.3, 10.0, and 8.67 at early, mid and late fruiting stages, respectively) was found from T_7 (bait trap + pheromone trap + Voliam flexi 300 SC). The highest weight of fruits plant^{-1} at early and mid fruiting stages (895.33 g and 1050.00 g, respectively) was also found from the same treatment but at late fruiting stage the highest weight of fruits plant^{-1} (870.67 g) was recorded from T_5 (bait trap + insecticide). Conversely, the lowest number of healthy fruits plant^{-1} (2.33, 3.33 and 1.67 at early, mid and late fruiting stages respectively) and weight of fruits plant^{-1} (204.33, 347.33 and 229.33 g at early, mid and late fruiting stages, respectively) were harvested from T_8 (Control) treatment.

In terms of infested fruits plant^{-1}, the lowest (1.00, 1.33 and 1.00 at early, mid and late fruiting stages, respectively) was found from T_7 (bait trap + pheromone trap + Voliam flexi 300 SC). The lowest weight of infested fruits plant^{-1} at early and mid fruiting stages (120.67 and 121.67 g, respectively) was found from the same treatment (bait trap + pheromone trap + Voliam flexi 300 SC) but at late fruiting stage the lowest weight of fruits plant^{-1} (117.67 g) was found from T_5 (bait trap + Voliam flexi 300 SC). In contrast, T_8 (untreated control) gave highest number of infested fruits plant^{-1} (4.33, 4.00 and 4.67 at early, mid and late fruiting stages, respectively) and maximum weight of infested fruits plant^{-1} (419.67, 511.67 and 453.33 g at early, mid and late fruiting stages respectively).

In terms of yield performance, the highest healthy fruit yield (18.24 t ha^{-1}) and highest total fruit yield (21.22 t ha^{-1}) was found from T_7 (bait trap + pheromone trap +Volium flexi) whereas the lowest (5.21 and 14.44 t ha^{-1} respectively) from control treatment (T_8).

In case of percent infestation of fruit by number and weight, most of the cases T_7 (Bait trap + pheromone trap + Voliam flexi 300 SC) gave the best performance except late fruiting stage considering percent fruit infestation by weight where T_8 (control) showed lowest at all growth stages. Regarding percent reduction of fruit infestation over control, treatment T_7 (bait trap + pheromone trap + Voliam flexi 300 SC) showed the best results.

Regarding correlation between healthy fruit weight/plant and incidence of cucurbit fruit fly, it was found that incidence of cucurbit fruit fly significantly decreased healthy fruit weight/plant with the increasing of cucurbit fruit fly population, i.e. negative correlation was observed between healthy fruit yield/plant and incidence of cucurbit fruit fly.

From the above results, it can be concluded that the treatment, T_7 (bait trap + pheromone trap + Voliam flexi 300 SC) performed as the best treatment for controlling cucurbit fruit fly and achieving highest healthy fruit yield of cucumber. Further trial in farmer's field is needed for validation of the study.

CHAPTER VI

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APPENDIX

Appendix I. Agro-Ecological Zone of Bangladesh showing the experimental location

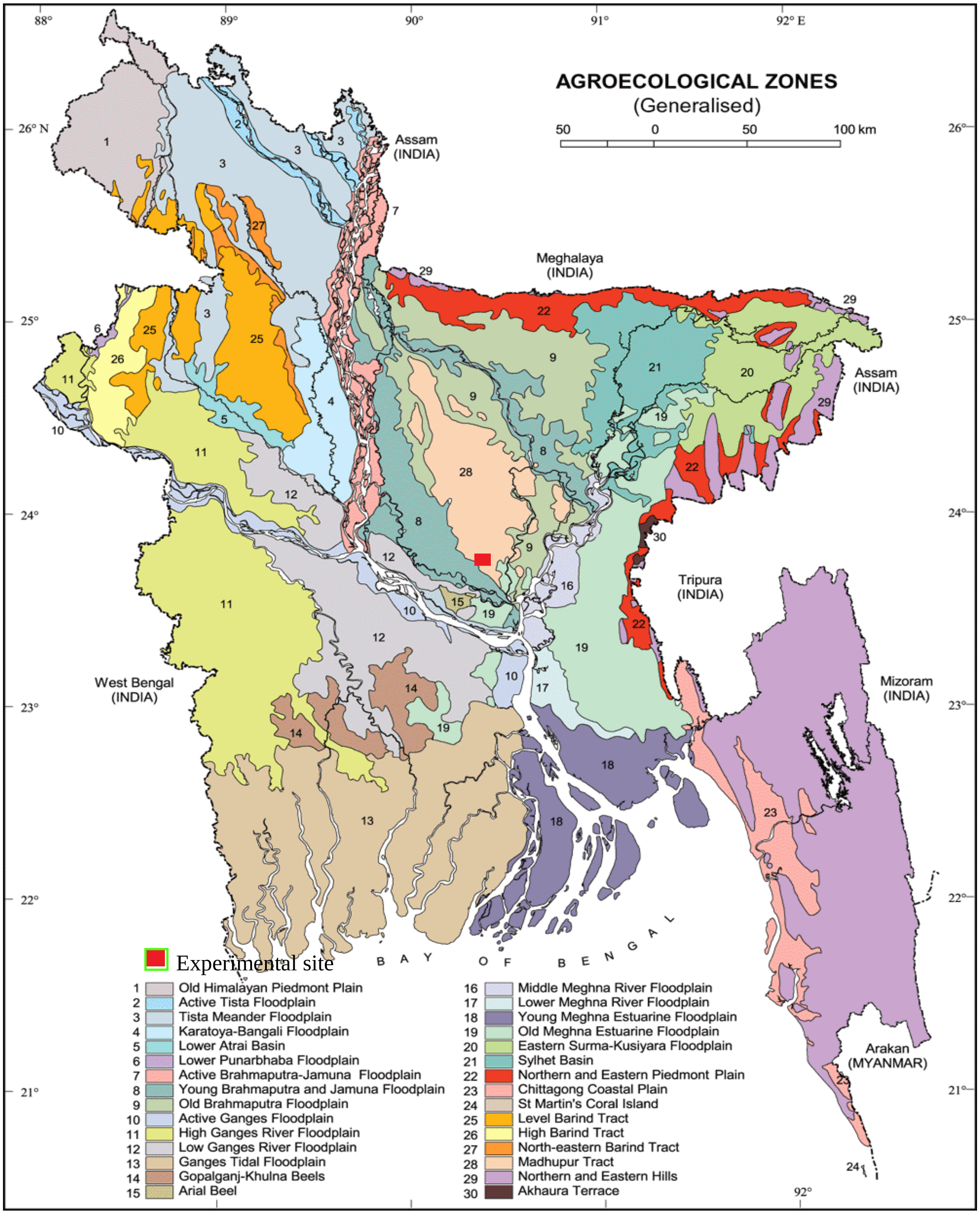

Fig. 10.Experimental site

Appendix II. Monthly records of air temperature, relative humidity, rainfall and sunshine hours during the period from December,2016 to March, 2017

Month	RH (%)	Air temperature (C)			Rainfall (mm)
		Max.	*Min.*	*Mean*	
December, 2016	54.80	25.50	6.70	16.10	0.0
January, 2017	46.20	23.80	11.70	17.75	0.0
February, 2017	37.90	22.75	14.26	18.51	0.0
March, 2017	52.44	35.20	21.00	28.10	20.4

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1212.

Appendix III. Characteristics of experimental soil analyzed at Soil Resources Development Institute (SRDI), Farmgate, Dhaka.

A. Morphological characteristics of the experimental field

Morphological features	**Characteristics**
Location	Agronomy Farm, SAU, Dhaka
AEZ	Modhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	Not Applicable

Source: Soil Resource Development Institute (SRDI)

B. Physical and chemical properties of the initial soil

Characteristics	**Value**
Partical size analysis % Sand	27
%Silt	43
% Clay	30
Textural class	Silty Clay Loam (ISSS)
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20
Exchangeable K (me/100 g soil)	0.1
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI)

Appendix IV. Layout of the experiment field

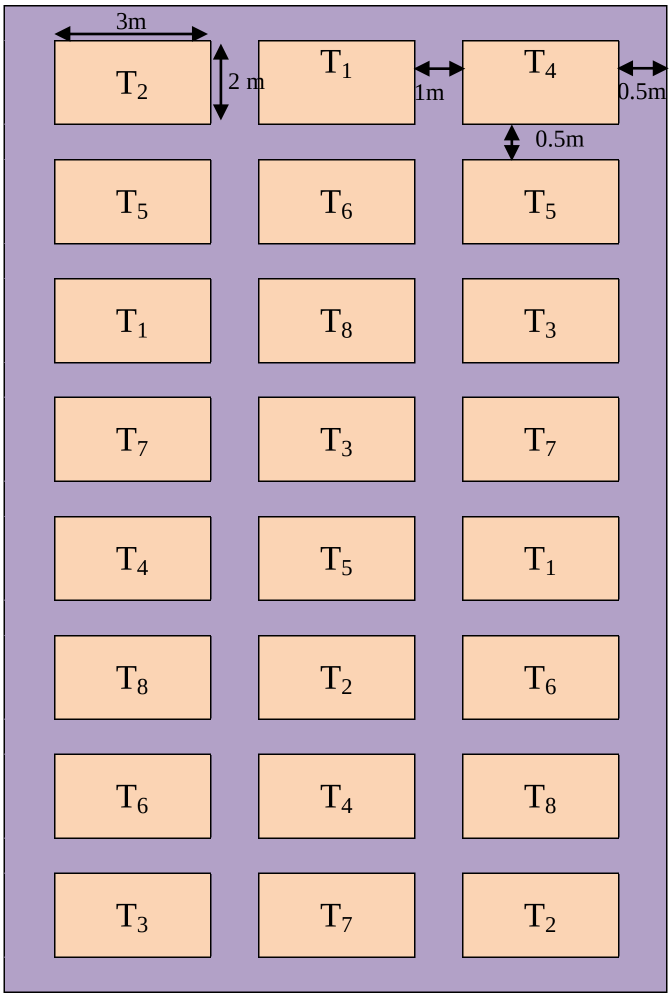

Fig. 11. Layout of the experimental plot

AppendixV: Effect of different traps and insecticides against cucurbit fruit fly on cucumber infestation by number at early fruiting stage

Sources of variation	Degrees of freedom	Number of fruits plant^{-1}			Percent infestation by number
		Healthy	Infested	Total	
Replication	2	1.067	0.312	1.105	0.531
Factor A	7	11.52*	5.103**	13.26*	8.371*
Error	14	1.204	0.317	1.114	2.052

** = 1% level of significance * = 5% level of significance

Appendix VI: Effect of different traps and insecticides against cucurbit fruit fly on cucumber infestation by weight at early fruiting stage

Sources of variation	Degrees of freedom	Weight of fruits plant^{-1} (g)			Percent infestation by weight
		Healthy	Infested	Total	
Replication	2	2.118	1.501	2.316	0.763
Factor A	7	21.834**	18.435*	24.257*	13.576*
Error	14	3.226	2.914	4.338	2.173

** = 1% level of significance * = 5% level of significance

Appendix VII: Effect of different traps and insecticides against cucurbit fruit fly on cucumber infestation by number at mid fruiting stage

Sources of variation	Degrees of freedom	Number of fruits plant^{-1}			Percent infestation by number
		Healthy	Infested	Total	
Replication	2	0.471	0.118	1.086	0.514
Factor A	7	9.448*	4.053**	11.731*	10.074*
Error	14	1.086	0.412	2.066	1.152

** = 1% level of significance * = 5% level of significance

Appendix VIII: Effect of different traps and insecticides against cucurbit fruit fly on cucumber infestation by weight at mid fruiting stage

Sources of variation	Degrees of freedom	weight of fruits plant^{-1} (g)			Percent infestation by weight
		Healthy	Infested	Total	
Replication	2	2.471	1.287	2.689	1.046
Factor A	7	23.071*	16.637*	28.075*	15.311**
Error	14	3.119	3.193	2.937	3.624

** = 1% level of significance * = 5% level of significance

Appendix IX: Effect of different traps and insecticides against cucurbit fruit fly on cucumber infestation by number at late fruiting stage

Sources of variation	Degrees of freedom	Number of fruits plant^{-1}			Percent infestation by number
		Healthy	Infested	Total	
Replication	2	0.478	0.271	0.836	0.712
Factor A	7	10.37*	6.204*	14.07*	7.221*
Error	14	0.758	0.283	1.064	1.171

** = 1% level of significance * = 5% level of significance

Appendix X: Effect of different traps and insecticides against cucurbit fruit fly on cucumber infestation by weight at late fruiting stage

Sources of variation	Degrees of freedom	Weight of fruits plant^{-1} (g)			Percent infestation by weight
		Healthy	Infested	Total	
Replication	2	1.856	1.314	2.589	0.763
Factor A	7	19.214*	15.116**	27.02*	11.827**
Error	14	2.759	2.344	3.851	1.766

** = 1% level of significance * = 5% level of significance

Appendix XI: Effect of different traps and insecticides against cucurbit fruit fly on yield ha^{-1} of cucumber

Sources of variation	Degrees of freedom	Fruit yield ha^{-1} (t)		
		Healthy fruit yield (t ha^{-1})	Infested fruit yield (t ha^{-1})	Total fruit yield (t ha^{-1})
Replication	2	0.212	0.175	0.412
Factor A	7	14.26*	7.055*	10.357*
Error	14	1.342	1.056	1.539

** = 1% level of significance * = 5% level of significance

Appendix XII: Incidence of cucurbit fruit fly plot^{-1} by number at different growing season of cucumber

Sources of variation	Degrees of freedom	Incidence of cucurbit fruit fly at			
		Early fruiting stage	Mid fruiting stage	Late fruiting stage	Total
Replication	2	0.024	0.012	0.018	0.026
Factor A	7	1.115*	1.026*	1.008**	1.114*
Error	14	0.012	0.016	0.014	0.024

** = 1% level of significance * = 5% level of significance