BIOLOGY OF CUCURBIT FRUIT FLY, *BACTROCERA CUCURBITAE* AND EFFICACY OF DIFFERENT TRAPS FOR ITS CONTROL ON BOTTLE GOURD, *LAGENARIA SICERARIA*

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CERTIFICATE

This is to certify that the thesis entitled '**BIOLOGY OF CUCURBIT FRUIT FLY, *BACTROCERA CUCURBITAE* AND EFFICACY OF DIFFERENT TRAPS FOR ITS CONTROL ON BOTTLE GOURD, *LAGENARIA SICERARIA*'** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **Master of Science in Entomology,** embodies the result of a piece of *bonafide* research work carried out by **Md. Mahmudul Hasan Sohel, Registration number: 11-04406** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: December, 2016
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DEDICATED TO

MY

BELOVED PARENTS

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ABSTRACT

Two sets of experiment were conducted in the laboratory of the Department of Entomology and experimental field, Sher-e-Bangla Agricultural University, Bangladesh during October, 2016 to March, 2017 using bottle gourd variety 'BARI-Lau 1'. Incase of biology, the mean incubation, larval (1^{st}, 2^{nd} and 3^{rd} instars), pre-pupal, pupal and total developmental periods of *B. cucurbitae* were 1.69±0.28, (1.72±0.33, 1.41±0.31, 2.31±0.51), 0.74±0.17, 9.2±0.78 and 36±1.69 days, respectively. The mean adult longevity, with food and without food was 14.1±1.28 and 5.0±0.81 days, respectively. The morphometric measurements of different stages of *B. cucurbitae* were also recorded. Incidence of *B. cucurbitae* as maggot population in bottle gourd was higher in January. Treatments for the management were T_1 = Pheromone Trap, T_2 = Bait trap with sweet gourd mashed, T_3 = Vinegar with rotted fruit trap, T_4 = Bait trap with banana mashed, T_5 = Funnel pheromone Trap, T_6 = Sticky board trap, T_7 = Untreated control and laid out in a Randomized Complete Block Design (RCBD) with three replications. The highest adult captured in T_5 (Funnel Pheromone trap) at different days interval, whereas the lowest (3.07) was captured in T_6 (Sticky board trap) and no adult was caught in T_7 (untreated control) treatment. Considering the all yield attributing characteristic, such as percent healthy and infested fruits by both weight and number, percent infestation over control, total yield, the treatment T_5 showed the best performance for controlling of the *B. cucurbitae* among all the treatments. T_1 showed the second highest performance, whereas, T_6 showed the lowest performance. The lowest total fruit yield (57.32 t/ha) was obtained in T_7, followed by T_6 treatment during the cropping season of bottle gourd.

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CHAPTER I

INTRODUCTION

The agro-ecological condition of Bangladesh is highly favorable for the cultivation of cucurbit vegetables. The constraints to sustainable increased productivity of cucurbit vegetables are many. A major and common one is the high incidence of insect pests, and management practices. The extent of damage varies from year to year, season to season and locality to locality depending on the seasonal abundance of the pests affected by the influence of prevailing abiotic and biotic factors and impact of control measures adopted (Anon., 2001). The basic requirement is to study the biology of the pest on its growth and development on longevity, fecundity, and mortality in relation to the host plants. Research works in this aspect are scanty in Bangladesh. Bangladesh has a long history of growing some cucurbits which include bottle gourd, water melon, and muskmelon as dessert crops, cucumber as salad and bitter gourd, snake gourd, sponge gourd, ribbed gourd as vegetables. The total area of cucurbit crops is around 81,720 hectares and the total production is about 308096 metric tons (BBS, 2008). Bottle gourd is primarily a winter vegetable but now days it is available also in summer. Now bottle gourd is grown round the year. They are grown in homestead for family consumption as well as in larger plots for commercial purpose. Unfortunately, cucurbits are infested by a number of insect pests, which are considered to be the significant obstacles for its economic production. Among them, cucurbit fruit fly and red pumpkin beetle are the major pests responsible for considerable damage of cucurbits (Butani and Jotwai, 1984).

Fruit fly is one of the most serious pests of cucurbits in Bangladesh (Alam, 1969; Akhtaruzzaman *et al*., 1999 , 2000). This pest is also known as melon fly and sometimes as cucurbit fruit fly. It was reported that *Bactrocera cucurbitae* and *Bactrocera cudata* are two species of cucurbit fruit fly which are commonly found in Bangladesh (Alam *et al.*, 1969). *B. tau* and *B. ciliates* have been currently identified in Bangladesh of which *B. ciliates* is a new record. *B. cucurbitae* is dominant in all the locations of Bangladesh followed by *B. tau* and *B. ciliates (*Akhtaruzzaman *et al*., 1999). The quantitative and qualitative damages due to this pest cause great economic loss to cucurbit vegetables growers almost all over the world. The damage caused by fruit fly is the most serious in melon and this may be up to 100 percent. Other cucurbitaceous fruits may also be infested upto 50 percent (Atwal, 1993). Yield losses due to fruit infestation vary from 19 to 70 percent in different cucurbits (Karim, 1995; Kabir *et al.,* 1991). Shah *et al.* (1948) observed the symptom of infestation as the formation of brown resinous deposit on the attracted fruits. The female fly drums on the skins of young fruits by her oviposit and sometimes on the young leaves or stems of the host plants and makes punctures for laying eggs. Afterward, fruit juice oozes out which transforms in to resinous brown deposit. After hatching in the fruit, the larvae feed into pulpy tissue and make tunnels in fruits and cause direct damage. They also damage the fruits indirectly by contaminating with frass and accelerated rotting of fruits by pathogenic infection. Infested fruits if not rotten, become deformed and hardly which make it unfit for consumption. In Bangladesh where the production of vegetables is much below the requirements, the damage due to cucurbit fruit flies is undesirable. It is therefore, extremely important to devise means to reduce the extent of damage due to fruit flies without affecting the agro ecosystem.

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. Pheromone traps attract only male fruit flies but this could be used as indicators of the total population. Pheromones are also increasingly efficient at low population densities, they do not adversely affect natural enemies, and they can, therefore, bring about a long-term reduction in insect populations that cannot be accomplished with conventional insecticides (Toledo *et al.,* 2010*).* The fruit flies have long been recognized to be susceptible to attractants. A successful suppression programme has been reported from different research works, where mass trapping using to reduced the infestation of *Bactrocera zonata* below economic injury levels..

In Bangladesh farmers solely rely on chemical pesticide for their welfare against this obnoxious insect pest and fail at most of the cases and damage the ecological balance. The application of insecticide, however, can cause several problems such as development of insecticide resistance pest insects, induction of resurgence of target pests, outbreak of secondary pests and undesirable effect on non-target organisms as well as serious environment pollution. Insecticide residues can exist in fruit which cause health hazard to consumers. Considering the hazardous impact of chemical pesticides on non-target organisms as well as environment, my study will be undertaken to assess the losses caused by *B. cucurbitae* and efficacy of different traps to get rid up fruit fly and aiming at development of eco-friendly and sustainable pest management system in cucurbits so that farmer can get satisfactory yield as well as consumer can get nontoxic fresh bottle gourd.

In view of the above facts, the main focus of this research work is lying in the following specific objectives:

- To study the different stages of cucurbits fruit fly, *B. cucurbitae* on host bottle gourd, *Lagenaria siceraria*
- To find out the capturing efficiency of different traps against fruit fly, in cucurbit vegetable bottle gourd
- To highlight the establishment of an environmentally safe control measure in cucurbit crops which help to reduce the use of chemical pesticides

CHAPTER II

REVIEW OF LITERATURE

The cucurbit fruit fly, *Bactrocera cucurbitae* is one the most damaging insect pest of cucurbit vegetables. It causes great yield reduction, which is considered as an important obstacle for economic production of these crops. Substantial works have been done globally on this pest regarding their origin, distribution, biology, seasonal abundance, host range, nature of damage, yield loss, rate of infestation and control measures. The information related to the studies reviewed is given below under the following sub-headings.

2.1 Systemic position of cucurbit fruit fly

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

2.2 Synonyms

Bactrocera cucurbitae (Coquillett) has also been known as:

i) *Chaetodacus cucurbitae*

ii) *Dacus cucurbitae*

iii) *Strumeta cucurbitae*

iv) *Zeugodacus cucurbitae*

2.3 Origin and distribution of fruit fly

Fruit flies are distributed all over the world and infest a large number of host plants. it is considered to be the native of oriental, probably India and South East Asia and it was first discovered in the Yacyama 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 (Atwal 1993 and Alam, 1965). It is also a serious pest in Mediterranean region (Andrewartha and Birch,1960). Although, this pest is widely distributed but it does not occur in the UK, central Europe and continental USA (Mckinlay *et al*., 1992).

According to Kapoor (1993)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 plants are widespread, either naturally or cultivation by man. Two of the world most damaging Tephritids, *Bactrocera dorsalis* and *Bactrocera cucurbitae*, are widely distributed in Malaysia and other South East Asian countries (Vijaysegaran, 1987). Gapud (1993) has cited references of five species of fruit fly in Bangladesh e.g., *B. brevistylus* (melon fruit fly), *Bactrocera caudatus* (fruit fly) (strumeta), *B. cucurbitae* (melon fly), *B. dorsalis* Hendel (mango fruit fly) and *B. zonatus* (zonata fruit fly).

Akhtaruzzaman (1999) reviwed that *Bactrocera cucurbitae, Bactrocera tau* and *Bactrocera ciliates* have been currently identified in Bangladesh of which *Bactrocera ciliatus* is a new record. *Bactrocera cucurbitae* is dominant in all the locations of Bangladesh followed by *Bactrocera tau* and *Bactrocera cilialus*.

2.4 Host range of fruit fly

Many fruit fly species do serious damage to vegetables, oil-seeds, fruits and ornamental plants. In Bangladesh, Alam (1962) recorded ten cucurbit vegetables as the host of fruit fly. Tomato, green pepper, papaya, cauliflower, mango, guava, citrus, near. fig and peaches are also infested by fruit fly (Atwal, 1993 and Anon., 1987).

Kabir *et al*. (1991) reviewed that sixteen species of plants act as the host of fruit flies among which sweet gourd was the most preferred host of both *B. cucurbitae* and *B. tau*. Among flowers, the rate of infestation was greater in sweet gourd but the intensity was higher in bottle gourd. Batra (1953) listed as many as 70 hosts of fruit fly species whereas Christenson and Foote (1960) reported more than 80 kinds of vegetables and fruits as the hosts.

Pandey *et al.* (2008) reported that more than 100 plant species have been recorded as hosts of melon fly worldwide, it commonly infests the cucurbitaceous (melon, squash and gourds) and Solanaceous (tomatoes and peppers) crops. Melon fruit fly damages over 81 plant species.

Lawrece (1950) recorded that cucurbit vegetables are the most favourite host of *B. cucurbitae*. Batra (1968) observed that the male flowers and flowers bud of sweet gourd were found to serve as usual host with anthers being the special food for the larvae and only occasionally small sweet gourd fruits being attacked perhaps through the female flower. Melon fruit fly infestation was recorded at 3-day intervals from the initiation of fruiting until the last picking. Among the cucurbits, long melon (*Cucumis melo*) was the most preferred host by the melon fruit fly, followed by round gourd (*Citrullus lanatus* var. *fistulosus*) and ridge gourd (*Luffa acutangula*). Pumpkin (*Cucurbita moschata*) was the least preferred host, followed by bottle ground (*Lagenaria siceraria*) and mateera (local cultivar of *Citrullus lanatus*). Cucumber (*Cucumis sativus*), sponge gourd (*Luffa acutangula*) and bitter gourd (*Momordica charantia*) were moderately preferred crops (Jakhar and Pareek, 2005).

According to Narayanan and Batra (1960), different species of fruit fly attack a wide variety of fruits and vegetables such as mango, guava, loquat, plum, peach, apple, quince, persimmon, banana, pomegranate, jujube, sweet lime, orange, chilies, jack fruit, carambola, papaya, avocado, bread fruit, coffees, berries, passion fruit, star apple, Spanish pepper, cucurbit fruit, cherries, black berry , grapes etc

2.5 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}.

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; Hollingsworth *et al*., 1997).

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; Chelliah, 1970; Chawla, 1966).

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. 53 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).

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).

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)*. 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.

B. 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).

2.6 Nature of damage of cucurbit fruit fly

According to Kapoor (1993), some flies make mines and a few from galls on different Darts of the plants. Singh (1984) reviewed that the maggots bore and feed inside the fruits causing sucken discolored patches, distortion and open cracks. Affected fruits prematurely ripe and drop from the plant. The cracks on fruit serve as the predisposing factor to cause pathogenic infection resulting in decomposition of fruits.

The fly has been observed to be active in the field almost throughout the year where the weather is equable (Narayanan and Batra, 1960). Tanaka and Shimada (1978) reported that population of melon fly was increased in autumn and decreased in winter in Kikai islands of Japan. Amin (1995) observed the highest population incidence at ripening stage of cucumber in Bangladesh.

According to Janjua (1984) the nature of infestation of fruit fly varies with the kinds of fruits. Shah *et al.* (1984) and York (1992) observed the formation of brown resinous deposits on fruits as the symptom of infestation. The insertion of the ovipositor causes wounds on the fruits and vegetables in the form of puncture. The adult female lays eggs just below the epidermis or sometimes a little deeper in the pulp, and/or sometimes on the young leaves or stems of the host plants. After that fluid substance oozes out which transform into a brown resinous deposits. After hatching, the larva feed into pulpy tissues and make tunnels in fruits causing direct damage.

2.7 Seasonal abundance of cucurbit fruit fly

Sujit (2005) cited that 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 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). Tanaka *et al*., (1978) reported that population of melon fly was increased in autumn and decreased in winter in Kikai islands Japan. Narayan and Batra (1960) reported that most of the fruit fly species are more or less active at temperatures ranging between 12ºC-15ºC and become inactive below 10°C. Cucurbit fruit flies normally increase their multiplication when the temperature goes below 15°C and relative humidity varies from 60-70 % (Alam, 1966). The peak population of fruit fly in India is attained during July and August in rainy months and January and February in cold months (Nair, 1986). The adults of melon fly, *B. cucurbitae* over winter November to December and the fly is the most active during July to August (Agarwal *et al*., 1987). Fruit fly populations were in general positively correlated with temperature and relative humidity. Amin (1995) observed the highest population incidence at ripening stage of cucumber in Bangladesh.

2.8 Rate of infestation at yield loss by cucurbit fruit fly

York (1992) reviewed that the loss of cucurbits caused by fruit fly in South East Asia might be up to 50%. Kabir *et al*. (1991) reported that yield losses due to fly infestation varies in different fruits and vegetables and it is minimum in cucumber (19.19%) and maximum in sweet gourd (69.96%). The damage caused by cucurbit 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 gone up to 50% (Atwal, 1993).

Shah *et al.* (1948) reported that the damage done by fruit flies in North West Frontier Province (Pakistan) cost an annual loss of over $ 655738.

Gupta (1992) investigated the rate of infestation of *B. cucurbitae* and *B. tau* on cucurbit in India during 1986-87 and recorded that 80% infestation on cucumber and bottle gourd in

July-August and 50% infestation on bitter gourd, 50% infestation on sponge gourd in August-September. Lee (1972) observed that the rate of infestation in bottle gourd and sweet gourd flowers were 42.2 ± 8.6% and 77.1 ± 3.5%, respectively the highest occurring in sweet gourd (32.5±3.9) and the lowest in sponge gourd (14.7 4.0).

Borah and Dutta (1997) studied the infestation of tephritids on the cucurbits in Assam, India and obtained the highest best fruit fly infestation rate in snake gourd (62.02%). Larger proportion of marketable fruits was obtained from ash gourd in and bottle gourd in summer season. Snake gourd and pumpkin yielded the lowest proportion of marketable fruits.

2.9 Management of cucurbit fruit fly

Fruit fly is the most damaging factor of cucurbits almost all over the world. Although there are various methods are available to combat this cost, there is not a single such method which has far been successfully reduced the damage of fruit fly. This perhaps is mainly due to polyphagus nature of these pests that helps their year round population build-up .the available literatures on the measures for the controlling of these flies are discussed under the following sub-heading:

2.9.1 Ploughing of soil

The pupal stage of fruit fly, it pupates in soil and also over winter in the soil. In the winter period, the soil n the field s turned over or given a light ploughing ; the pupa underneath are exposed to direct sunlight and killed . They also become prey to the predators and parasitoids. A huge number of pupae are died due to mechanical injury during ploughing. (Agarwal *et al.*, 1987; Chattopadhyay, 1991; Nasiruddin and karim, 1992; Kapoor, 1993).

2.9.2 Field sanitation

The female fruit fly lay eggs and the larvae hatch inside the fruit, it become essential to look for the available measure to reduce their damage on fruit. One of the Safety measures is the field sanitation (Nasiruddin and karim, 1992). Field sanitation is an essential prerequisite to reduce the insect population or defer the possibilities of the appearance of epiphytotics or epizootics (Reddy and Joshi, 1992). According to Kapoor (1993), in this method of field sanitation, the infested fruits on the plat or fallen on the ground should be collected and buried deep into the soil or Cooked and fed to animals.

2.9.3 Management with different trap

Different kinds of bait traps are available for management of cucurbit fruit fly. These traps are discussed under following sub-heading:

2.9.3.1 Managemaent with pheromone trap

Results of an experiment on monitoring the sweet potato weevil in the farmers' field by sex pheromones at the river belt of Jamalpur revealed that sweet potato weevils were a problem in this area. The idea on the weevil population density in the field can guide the farmers to schedule their proper management Anon (1993) Cheng and Struble (1982) conducted an experiment on field evaluation of black light, sex attractant traps for monitoring seasonal distribution of the dark sided cutworm (Lepidoptera Noctuidae) in Ontario. Of these, the dark sided cutworm, *Euxoa messoria*, as expected, was the most numerous over the 5- year study. These results proved, further, that the sex attractant trap is highly specific.

The effect of the height of sex attractant traps on catches of male *E. messoria* moths in the field was consistent among the years. In general, all baited traps, regardless of the height, caught significantly more moths as compared with the unbaited traps. Although there were no significant differences between the catches of traps set at 1.0 m and 0.5 m above !he ground level, traps set at 0.5 m tented to capture more moths than the traps at 1.0 m above the ground level. The unbaited traps occasionally captured a moth by chance

Results of initial test comparing sex attractant with black light traps are presented. In the 5-year test, all sex attractant trap catches, regardless of the height, were much greater than black light trap catches. During the study period, the sex attractant traps captured 3155 male *E. messoria* moths, while the black light traps captured 205 *E. messoria* moths. The data clearly indicate that the sex attractant traps were more effective than the black light traps for trapping moths of *E. messoria* in an open field.

This make them superior to black light traps for monitoring population of this species especially considering their species specificity, low cost and convenience (Cheng and Struble, 1982). The sex attractant traps provide more exact information about the activity of the *E. messoria* populations than the black light traps and they should be valuable aid in predicting outbreaks of this pest. In addition this technique can easily be fitted into a system of integrated pest management program the monitoring station or farm level.

Kehat *et al*. (1998) observed that suppression of mating of *H. armigera* females was high throughout the entire test (49 days), even at high population levels, particularly with the two-component blend (mixture of two pheromone component) and it was significantly better than that obtained with the five-component (mixture of five pheromone component) blend. When percentage mating was determined by using six to eight mating tables per plot each containing one female, the two-component blend was, again, very effective but on two occasions (days 26, 34) there was a low percentage of mating.

The five component blend was, in this case, clearly inferior to the two-component blend and low percentages of mating (15-30%) were observed more often. Statistical analysis indicated that the use of six to eight mating table each containing one female per table, was significantly more sensitive in detecting percent mating than the use of two mating tables, each containing five to seven females. Each of the two methods showed that the binary blend was significantly better in disrupting mating of *H. armigera* than the five- component blend. On test 2 mating of *P. gossypiella* females in the HPROPE treated plot were completely suppressed throughout the entire test (161 days). Mating percentages of sentient females in the control were low in this test. On test 3, this mating disruption test was conducted only against *P. gossypiella*, using “PBW rope L” pheromone. It was sufficient to achieve complete suppression of male captures and of mating during the 75 days of the field experiment.

Mating disruption of Yellow Stem Borer (YSB) by pheromone was tested by Cork *et al*. (1992) and they observed the tiller and particle assessments and the effects of mating on final yield. In order to compare damage estimates for the treatment plot for DH (Dead heart), and

WH (White heads), data from 21 to 41 DAT and 69 to DAT respectively, were used. The results show that the level of DH damage in the farmers' practice plot was lower than that in either the untreated control pheromone treated plots, but the differences were not statistically significant. However, the levels of WH damage recorded in the farmers' practice and the untreated control plots were significantly higher than that observed in the pheromone treated plot Islam (1994) conducted an experiment on trapping of the male pulse beetle, *Callosobruchus chinensis* (L) (Coleoptera: Bruchidae), in the laboratory using crude extract of female sex pheromone and observed the trapping efficiency of a new plastic trap developed for *Callosobruchus chinensis* ;on the result of male response to pheromone baited traps containing crude female extract or live females he observed that there was no significant difference between the number of males caught with crude female extract or live females.

Tamaki *et al*. (1983) conducted an experiment on impact of removal of males with sex pheromone baited traps on suppression of the peach twig borer, *Anarsia lineatella* (Zeller). Male removal sex pheromone - baited traps has been successful in reducing damage caused by the red banded leafroller, *Agrotaenia velutinana* (Walker) (Trammel *el al*. 1974), the grapeberry moth, *Endopiza viteana* Clemens (Taschenberg *et al*., 1974). However, in few of these cases has the amount of damage observed been at or below corn commercially acceptable levels.

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.

IPM provides a role for alternative approaches such as cultural methods, use of predators, viruses and use of sex pheromone etc. Syngenta in Bangladesh in collaboration with UK's Department for International Development (DFID) and BRRI (Bangladesh Rice Research Institute) made program on mass trapping by sex pheromone to control Yellow Stem Borer (YSB) of rice in Comilla and Mymensingh districts for 2001-2003. The traps used in their program are inexpensive, easy to maintain and catch only male YSB. Farmers involved in the trials were so enthusiastic that they wanted pheromone for use on their other crops Anon (1983).

Akhtaruzzaman *et al*. (2000) conducted a field study with cucumber cv. Lamba Shasha in Bangladesh, from April to July 1998, to evaluate the efficacy of some bait sprays against fruit fly (*Bactrocera cucurbitae*) in comparison with a standard insecticide and a bait trap. The treatments comprised 0.5 ml diazinon 60EC mixed with 2.5 g molasses and 2.5 litres water at a ratio of 0.2:1:100 (T_1), fenitrothion (Sumithion 50EC) mixed with molasses (same preparation as T_1; T_2), 25 g molasses + 2.5 ml malathion (Limithion 50EC) and 2.5 litres water at 1:0.1:100 (T_3), 0.5 ml Nogos 100EC mixed with 100 g sweet gourd mash and 100 ml water (T_4), cover spray with 2.0 ml malathion/litre of water as standard insecticide (T_5), and untreated control (T_6). The bait sprays were applied at intervals of 15 days starting from the fruit initiation stage until 15 days before the final harvest. The effect of bait sprays on the infestation intensity per fruit was expressed in terms of percentages of fruit with infestation intensities corresponding to any of the 4 grades: low infestation intensity, 1 puncture per fruit (grade-I), moderate infestation intensity, 2 punctures per fruit (grade II), high infestation intensity, 3 punctures per fruit (grade III), and very high infestation intensity, >4 punctures per fruit (grade IV). T_3 satisfactorily reduced infestation and minimized the reduction in edible yield.

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 percent. 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.

To make the pheromone component, E-11 hexadacenyle acetate and E-1hexadacene- l.0l were used from 10:1 to 100:1 ratio. A tube filled with 2-3 mg of mixture was used in a trap for 6 weeks and it proved a significant result to reduce the BSFB population bellow the economic injury level.

2.9.3.2 Management with sweet gourd bait trap

Nasiruddin and Karim (1992) reported that bait spray (1.0 g Dipterex 80SP 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. Agarwal *et al.* (1987) achieved very good results for fruit fly (*Bactrocera cucurbitae*) management by spraying the plants with 500 g molasses and 50 litres of water at 7 days intervals. According to Steiner *et al.* (1988), poisoned bait containing Malathion and protein hydrolysate gave better results in fruit fly management program in Hawaii.

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 25 g 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).

2.9.3.3 Management with banana bait trap

Among the various protein baits tested, yeast, soybean, fruit fly diet, protein and casein were more female selective. When total fruit flies were considered, soybean + sugar + banana was the most superior protein bait with a fruit fly capture of 4.5/trap/week in guava, while casein + sugar + papaya attracted more female fruit flies with a mean capture of 4.33 in mango (Rajitha, 2004). Fruit fly diet + sugar + banana was the most superior protein bait with fruit fly capture of 8.00 fruit flies/trap/week in guava and 6.50 fruit flies/trap/week in mango. Ammonium acetate when used at 5 per cent of the bait mixture attracted more females (Ravikumar, 2005).

2.9.3.4 Management with vinegar trap: The fruit flies have long been recognized to be susceptible to attractants. A successful suppression programme has been reported from Pakistan where mass trapping with Methyl eugenol, from 1977 to 1979, reduced the infestation of *Bactrocera zonata* below economic injury levels (Qureshi *et al.,* 1981). *Bactrocera dorsalis* was eradicated from the island of Rota by male annihilation using Methyl eugenol as attractant (Steiner *et al.*, 1965). The attractant may be effective to kill the captured flies in the traps as reported several authors, one per cent Methyl eugenol plus 0.5 per cent Malathion (Lakshmann *et al.,* 1973) or 0.1 per cent Methyl eugenol plus 0.25 per cent Malathion (Bagle and Prasad, 1983) have been used for the trapping the oriental fruit fly, *Bactrocera dorsalis* and *Bactrocera zonata*. Neem beriatives have been demonstrated as repellents', anti-feedants, growth inhibitors and chemosterilant (Steets, 1976; Leuschner, 1972, Butterworth and Morgan, 1968). Singh and Srivastava (1985) found that alcohol extract of neem oil *Azadirachta indica* reduced oviposition per centage of *Bactrocera cucurbitae* on bitter gourd completely and its 20% concentration was highly effective to inhibit ovipositon of *Bactrocera zonata* on guava. Stark *et al.* (1990) studied the effect of Azadiractin on metamorphosis, longevity and reproduction of *Ceratilis Capitala* (Wiedemann), *Bactrocera cucurbitae* and *Bactrocera dorsalis*.

2.9.3.5 Management with sticky board trap

The discovery that certain colours attract certain species strongly, led to the use of the most powerful ones in the trapping devices. White objects are not very attractive to tephritids (Cytrynowicz *et al.,* 1982) but yellow traps baited with methyl eugenol were more attractive to *B. dorsalis* (Vargas *et al.,* 1991; Stark and Vargas, 1992). Yellow colour also attracted more olive fruit flies than any other colour (Prokopy *et al.*, 1975). Yellow traps have been tested for predicting the infestation levels based on captured females of *B. oleae* (Ballatori *et al.,* 1980; Mitchell and Saul, 1990). Jalaluddin *et al.* (1998), Madhura (2001) and Sarada *et al*. (2001) observed that greater preference of fruit flies towards yellow and transparent traps.

Studies were made on attraction of different species of fruit flies to different colored traps in guava and mango orchards near Dharwad during 2005-06. Yellow and transparent traps attracted significantly high number of *B. correcta* in guava (70.45 fruit flies/trap/week) and mango (5.13 fruit flies/trap/ week), respectively. Green and orange coloured traps in guava (3.79 and 3.75 fruit flies/trap/week, respectively) black coloured traps in mango (3.88 fruit flies/trap/week) were attractive to *B. dorsalis and B. zonata* was attracted to red coloured traps (3.75 fruit flies/trap/week) in mango ecosystem. When total fruit flies irrespective of species were considered, yellow colour traps were attractive in guava (71.91 fruit flies/trap/week) while black colour traps in mango (8.68 fruit flies/ trap/week) (Ravikumar and Virakthmath, 2007).

CHAPTER III

MATERIALS AND METHODS

Two set of experiments were conducted to study on the biology of the cucurbit fruit fly, *Bactrocera cucurbitae* and evaluate efficacy of different traps for its control on bottle gourd during the period from October 2016 to March 2017. The details materials and methods of this experiment are presented below:

Experiment 1: Study on the biology of the cucurbit fruit fly, *Bactrocera cucurbitae* in the laboratory

The investigation was being undertaken in the laboratory at the Department of Entomology, Sher-e-Bangladesh Agricultural University, Dhaka-1207 after fruiting of the bottle gourd in the experimental plot during the period of December 2016 to March 2017, on the biology of the cucurbit fruit fly, *B. cucurbitae*. The details of the experiment including the rearing of the test insects are furnished below:

3.1.1 Collection of eggs for the study of biology

Biology of cucurbit fruit fly, *B. cucurbitae***:** The infested fruits of bottle gourd (Plate 1) just after egg deposited by cucurbit fruit fly collected from the field and marked egg deposited area on bottle gourd, then excavating the infested fruit below oviposition puncture from marked egg deposited area of bottle gourd and observed under simple microscope for detected eggs of cucurbit fruit fly. After detection eggs (Plate 2) were collected and transferred in the petridish (2 cm ht. X 10 cm dia.) for hatching and data were recorded. After hatching the newly hatched larvae were transferred in another Petri dishes containing pulp of the bottle gourd. At the time of intervals different instars of larva observed and data were recorded (Plate 3).

The morphological characteristics of the larvae/maggot and pupae (Plate 4) were studied and recorded during the period of larval and pupal development, respectively. Different growth and development stages of cucurbit fruit fly such as

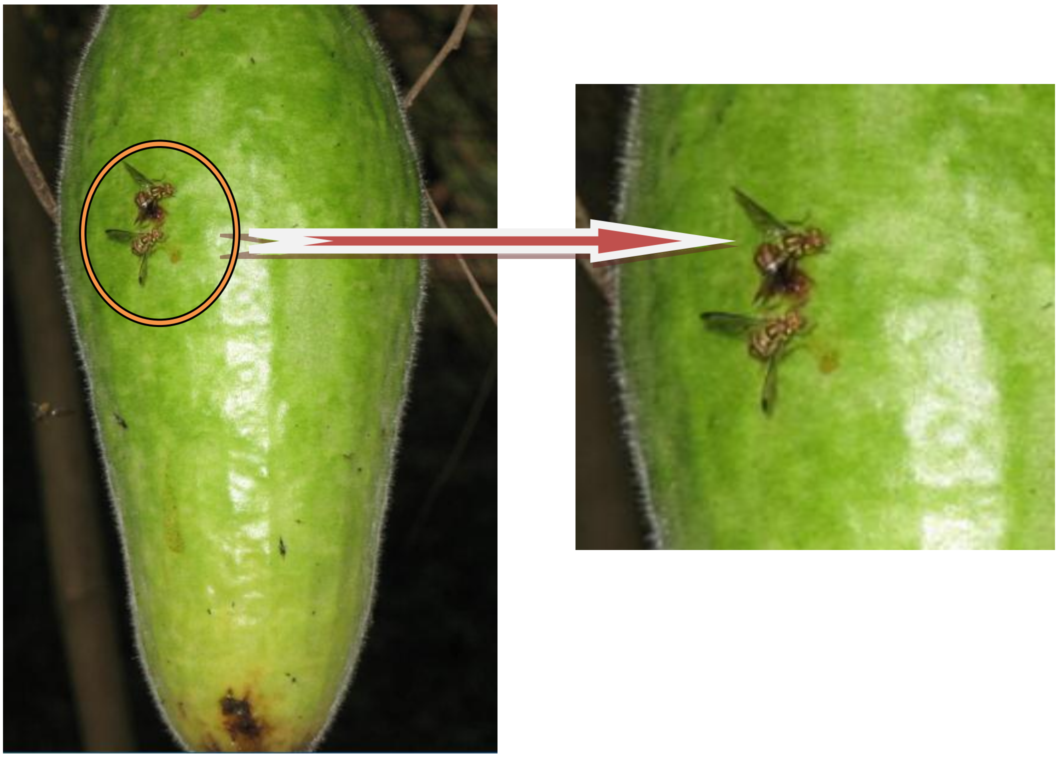

Plate 1: The infested fruits of bottle gourd (egg deposited by cucurbit fruit fly) in field

Plate 2: Eggs of cucurbit fruit fly, *B. cucurbitae* in microscopic view

incubation period, larval period, pupal period and adult longevity were recorded during the study. The incubation period was measured by time interval between egg laying and larval hatching. The emerged adults of cucurbit fruit fly were kept in the rearing case with food (10% honey solution into watch glass) and without food till their death and the adult longevity were recorded. Total development period of both male (Plate 5) and female (Plate 6) were also recorded.

3.1.2 Length and width of different stages of the insect: The length and width of different stages of the insect were measured under microscope and longer parts were measured with the help of slide calipers.

3.1.3 Larval and pupal mortality

The infested fruits of bottle gourd collected from the field kept in rearing case (1´X1´X 2´). Within the rearing case the infested fruits of bottle gourd were placed in a plastic tray. After ending of the larval period (when maggots come out from rotten fruit), the rotted fruits were removed. 50 maggots were kept in petridish with soil and it replicated five times. After 5 days the soils were sieved to collect pupa and counted from each petridish individually as well as larval mortality was recorded. For pupal mortality, 20 pupae were kept in glass jar for adults emerged. After adults emerged data were recorded and determined pupal mortality.

3.1.4 Incidence of cucurbit fruit fly

10 (ten) infested fruits of bottle gourd were collected from the experimental field at the 5 days intervals. Numbers of maggots were counted from each infested fruits of bottle gourd. Incidence pattern of cucurbit fruit fly as maggot population in bottle gourd were determined during the study period.

3.1.5 Design of the experiment: CRD (Completely randomized design) with 5 replications

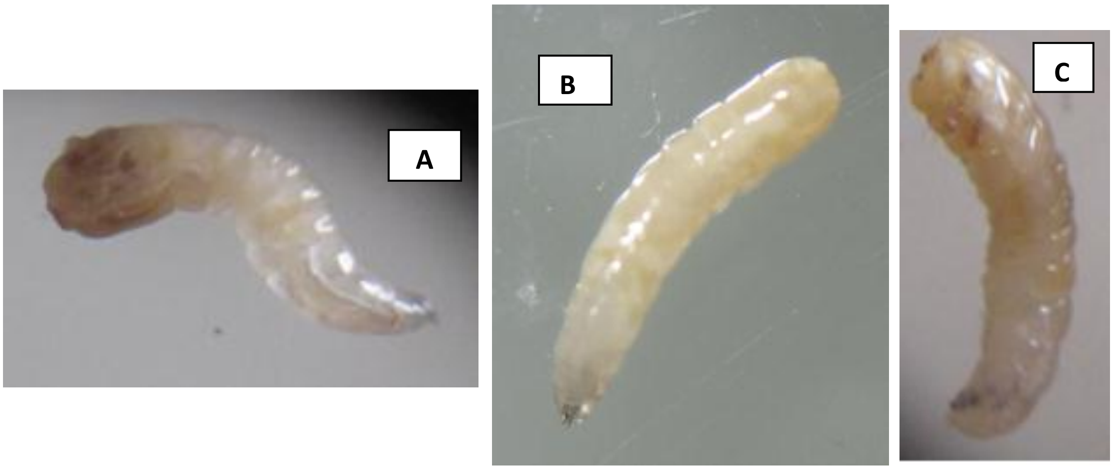

Plate 3: Different larval instars of cucurbit fruit fly, *B. cucurbitae*
(**A**-1st instar, **B-** 2nd inster and **C-** 3rd instar)

Plate 4: Pupa of cucurbit fruit fly, *B. cucurbitae*

3.16 Data to be recorded: Incase of study biology of *B. cucurbitae*, the data was recorded on the following parameters at the different time intervals given below:

- ✓ No. of egg deposition per selected sample
- ✓ Incubation period
- ✓ Larval period
- ✓ Pre-pupal period
- ✓ Pupal period
- ✓ Adult longevity
- ✓ Abundance of different growth and developmental stages
- ✓ Abiotic factors specially ambient temperature, relative humidity and light intensity

Plate 5: Adult male of cucurbit fruit fly, *B. cucurbitae*

Plate 6: Adult female of cucurbit fruit fly, *B. cucurbitae*

Experiment 2. Efficacy of different traps for the population Management of cucurbit fruit fly, *B. cucurbitae* on bottle gourd, *Lagenaria siceraria*

3.2.1 Experimental site

The experiment was conducted at the Farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh, which is situated in 23074/N latitude and 90035/E longitude (Anon, 1989).

3.2.2 Soil

The soil of the experimental area belongs to the Modhupur Tract (UNDP, 1988) corresponding AEZ No. 28 and is shallow red brown terrace soil. The land of the selected experimental plot is medium high under the Tejgaon series (FAO, 1988). The characteristics of the soil under the experimental plot were analyzed in the Soil Testing Laboratory, SRDI, Dhaka and has been presented in Appendix I.

3.2.3 Climate

The climate of experimental site was subtropical, characterized by the winter season from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October (Edris *et al*., 1979). Meteorological data related to the temperature, relative humidity and rainfall during the experimental period was collected from Bangladesh Meteorological Department (Climate Division), Sher-e-Bangla Nagar and has been presented in Appendix II.

3.2.4 Planting material

The variety BARI Lau 1 of Bottle gourd was selected for the experiment during Rabi season 2016-2017. The seed of this variety was collected from Bangladeesh Agricultural Research Institute, Joydebpur, Gazipur.

Plate 7: Experimental research field of bottle gourd during the study period

3.2.5 Experimental design and layout

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications in the central farm of SAU. The field with good tilth was divided into 3 blocks. Each block was sub-divided into 7 sub plots, each of which was of 3.5 m × 2.5 m maintaining plot to plot distance 1.0 m and row to row distance 0.5m (Fig. 1).

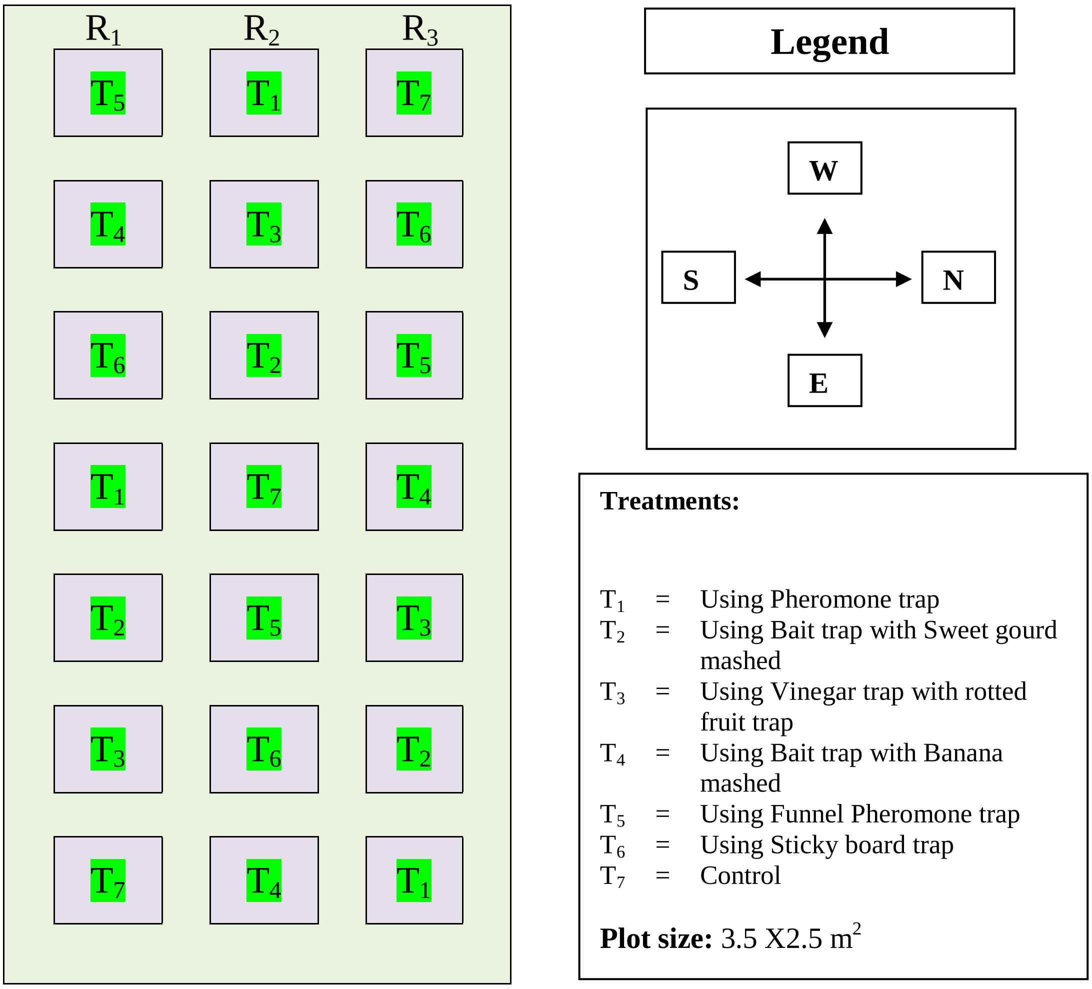

Figure 1. Layout of the experimental plot

3.2.6 Land preparation

The selected plot of the experiment was opened with a power tiller, and left exposed to the sun for a week. Subsequently cross ploughing was done two times with a country plough followed by laddering to make the land suitable for growth of Bottle gourd seedlings. All weeds, stubbles and residues were eliminated from the field. Finally, a good tilth was achieved. The Field layout was done on according to the design, after land preparation. The plots were raised by 10cm from the soil surface keeping the drain around the plots.

3.2.7 Fertilizer application

Urea, Triple Super Phosphate (TSP) and Muriate of Potash (MP) were used as a source of nitrogen, phosphorous, and potassium, respectively. Manures and fertilizers that were applied to the experimental plot presented in the following:

- Dose of application of fertilizers in sweet gourd field (BARI, 2015)

Fertilizers and Manures	Dose ha^{-1}
Cowdung	20 – 25 ton
Urea	200 kg
TSP	200 kg
MP	175 kg

The total amount of cowdung, Urea, TSP and MP was applied as basal dose at the time of land preparation. Urea was applied at four installments as 1^{st}, 2^{nd}, 3^{rd} and 4^{th} harvest respectively.

3.2.8 Seeds sowing, seedling raising and transplanting

Collecting seeds of BARI Lau 1 of Bottle gourd were soaked for 12 hours in water for rapid and uniform germination. Then seeds were sown in the polyethylene bags (12cm x 18cm) containing a mixture of equal proportion of well decomposed cowdung and loam soil in 1^{st} week of October 2016 and irrigated regularly. After germination, the seedlings were sprayed with water by hand sprayer and sprayed was done once a day for two weeks. Seedlings were placed in a shady place.

After 11 days of sowing, Seedlings were transplanted on 11th October, 2016 in the pits of the experimental field (two seedlings per pit and 2 pits per plot). At the time of transplanting, polyethylene bags was cut and removed carefully in order to keep the soil intact with root of the seedling. Finally one healthy plant was kept in each pit and damaged seedlings were replaced by new one.

Plate 8: Seedling in polyethene bag

3.2.9 Cultural practices

After transplanting of seedlings, a light irrigation was given. Subsequent irrigation was applied in all the plots as and when needed. After 7days of transplanting a single healthy seedling with luxuriant growth per pit was allowed to grow discarding others, propping of each plant by bamboo sticks (2.0m) was provided on about 1.5m high from ground level for additional support and to allow normal creeping. At initial vegetative and fruiting stage, infestation of red pumpkin beetle and others leaf eating insects were managed mechanically by hand picking. Weeding and others sanitations practices were done, whenever necessary for better growth and development of the bottle gourd plants.

3.2.10 Treatments of the experiment

T_1 = Using Pheromone trap

T_2 = Using Bait trap with Sweet gourd mashed at the 5 days interval

T_3 = Using Vinegar trap with rotted fruit trap

T_4 = Using Bait trap with Banana mashed at the 5 days interval

T_5 = Using Funnel Pheromone trap

T_6 = Using Sticky board trap

T_7 = Untreated control

3.2.11 Collection of trap and trap materials

The commercial formulation of Q-lure (Sex pheromone) with GME pheromone trap were collected from Ispahani Agro-Biotec Ltd. Konabari, Gazipur and local made /dwelling made different traps materials (such as Vinegar, Sweet gourd, Banana, rotted fruit, glue, insecticide etc.) were collected from local market.

3.2.12 Preparation of the different traps use as treatments

The pheromone, 'cuelure', which mimics the scent of female flies, attracts the male flies and traps them in large numbers resulting in mating disruption.

3.2.11.1 Sex pheromone trap: Pheromone trap was collected from Ispahani Agro-Biotec Ltd. Konabari, Gazipur and set in the experimental field (Plate 9). Sex pheromone trap designed by BARI with cue-lure 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 each.

Plate 9: Sex pheromone trap in the experimental field during the study period

Plate 10: Bait trap with mashed sweet gourd in the experimental field during the study period

3.2.12.2 Bait trap with sweet gourd mashed

The poison bait trap was prepared using mashed sweet gourd mixed with water and Sevin 50WP at the rate of 2gm per 100 gm of mashed sweet gourd. 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. The number of adult fruit flies (male and female) trapped in those bait traps were recorded at each four days interval in the morning. The old bait materials were changed at the interval of 4-5 days each and fresh ones were placed there for further use (Plate 10).

3.2.12.2 Vinegar trap with rotted or overripe fruit trap

It is a simple trap. This type of trap was prepared using vinegar 200ml with 2ml liquid dish soap and a piece of ripe or overripe fruit (papaya) 100gm. (At first, a plastic bottle was cutoff upper portion then all materials was kept in this plastic bottle and another cut portion inverted and insert into the mouth of the lower cut-portion of plastic bottle to form a makeshift funnel. Fruit fly entry by this funnel into vinegar trap and would not escape / get out from the trap. Vinegar traps were placed at 50 cm above the ground with the help of bamboo supports. (Plate 11).

3.2.12.4 Bait trap with Banana mashed This poison bait was prepared from mashed banana mixed with water and Sevin 50WP at the rate of 2gm per 100gm of mashed banana (Plate 12). Freshly prepared baits in earthen pots were placed at 50 cm above the ground with the help of bamboo supports. An earthen cover plate was placed 20 cm above the bait container to protect the bait material from sun and rain. Used baits were changed by freshly prepared baits within 3-4 days to attract more fruit flies.

3.2.12.5 Funnel pheromone trap

Pheromone trap was made up of a plastic bottle of with its both sides had two funnel. Cuelure was hanged inside the plastic bottle (Plate 13).

Plate 11: Vinegar trap with rotted or overripe fruit trap in the experimental field during the study period

Plate 12: Bait trap with banana mashed in the experimental field during the study period

Plate 13: Funnel pheromone trap in the experimental field during the study period

Plate 14: Sticky board trap in the experimental field during the study period

3.2.12.6 Sticky board Trap

Sticky board trap was prepared with a yellow hard paper and glue was used as a sticky substances and it was applied on the hard paper twice in a week (Plate 14).

3.2.13 Data collection

The whole reproductive period of sweet gourd was divided into three stages viz., early, mid and late fruiting stages. First flower initiation to 20 days was treated as early fruiting stage; 20 days to 40 days was called mid fruiting stage and after 40 days to the end of the final harvest was called late fruiting stage. The results of the effectiveness of different treatments were explained and discussed on the basis of some parameters The following parameters were considered and detailed methodology was given below:

The number of adult fly captured per week in different traps was recorded. The data on the number of healthy and infested fruits were recorded from each treatment. The effectiveness of each treatment was evaluated on the basis of some parameters. The following parameters were considered during data collection at each stage of reproduction.

3.2.13.1 Per cent fruit infestation by number

After harvesting the healthy fruits (Plate 15) and the infested fruits (Plate 16) were separated by visual observation. The number of healthy fruits and the infested fruits of early, mid and late fruiting stages were counted and the per cent fruit Infestation for each treatment was calculated by using the following formula:

$$\text{\% Fruit Infestation by number} = \frac{\text{Number of infested fruits}}{\text{Total Number of fruits (healthy + infested fruits)}} \times 100$$

3.2.13.2 Fruit yield

After harvesting, the weight of healthy fruits (Plate 18) and infested fruits were separately recorded the total yield under each treatment was finally converted to determine the

Plate 15: Healthy fruits of bottle gourd in experimental field during the study period

Plate 16: Infested fruits of bottle gourd due to *B. cucurbitae* in experimental field during the study period

Plate 17: Infested fruits of bottle gourd with maggots of cucurbit fruit fly*, B. cucurbitae*

yield (t/ha). The per cent increase and decrease of yield over control was computed by using the following formula:

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

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

3.2.13.3 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.

3.2.13.4 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.

3.2.13.5 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.

3.2.13.6 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.

3.2.14 Statistical analysis

Data were analyzed by MSTAT-C software for proper interpretation. The data recorded on different parameters were subjected to analysis of variance (ANOVA) and the means were compared according to Duncan's Multiple Range Test (DMRT) at 5% level of significance (Gomez and Gomez, 1984). Moreover, the graphical work was done using Microsoft Excel program.

Plate 18: After harvesting healthy bottle gourd from the experimental field

Plate 19: Completely matured fruit of bottle gourd in the experimental field

CHAPTER IV

RESULTS AND DISCUSSIONS

The research work was consists of two set of experiments on the study of biology of the cucurbit fruit fly, *Bactrocera cucurbitae* and evaluate roles of different traps for their controlling to produce safe vegetable during the period from October 2016 to March 2017. The results have been presented and discussed details under following heading and sub-heading:

4.1 Experiment 1: Study on the biology of the cucurbit fruit fly, *Bactrocera cucurbitae* in the laboratory

4.1.1 Duration and morphometrics measurement of different life stages of fruit fly, *B. cucurbitae* on Bottle gourd

Egg/oviposition period: The egg hatching period was 1.69±0.28 and the data ranges was1.0-2.0 (Table 1).

Larvae/Maggot: The larvae/Maggots were apodus. The matured maggots were cylindrical, pointed anteriorly or cephalic end blunt posteriorly. The larvae developed through three instars presented below:

First instar: The newly hatched maggot was white in color. Total 1.72±0.33 days required for first instar larvae (Table 01) and the data range was 1.4-2.0. The length and width of first instar maggot when reared on bottle gourd ranged from 0.49-0.65 mm and 0.20-0.25mm; mean value being 1.1± 0.9 mm (Mean± S.D.) and 0.22 ±0.11mm (Mean± S.D.) respectively.

Second instar: Total 1.41±0.31 days were required to complete second instar (Table 1). The length and width of second instar maggot when reared on bottle gourd data ranged from 3.0-4.0mm and 1.0-1.4mm; mean value being 3.03 ± 0.95 mm (Mean± S.D.) and 3.03 ± 0.95 mm (Mean± S.D.) respectively.

Third instar: Total 2.31±0.51 days were required to pass third instar maggot (Table 1). The maggot measured 6.42 ± 0.90 mm in length and 2.13 ± 0.20 mm in width when feeding on Bottle gourd fruit; the data range was 5.0-7.8 mm and 2.0-2.5 mm respectively (Table 2).

Table 1: Duration of different life stages of Cucurbit fruit fly, *B. cucurbitae* on Bottle gourd

Life stage		Duration in Days (Mean± SD)	Data range
Egg period		1.69±0.28	1.0−2.0
Larval longevity			
1st instar		1.72±0.33	1.4− 2.0
2nd instar		1.41±0.31	1.0−2.0
3rd instar		2.31±0.51	1.8− 2.7
Pre-pupal period		0.74±0.17	1.8−3.0
Pupal period		9.2±0.78	8.0−10
Adult longevity	Without Food	5.0±0.81	4.0−6.0
	With Food	14.1±1.28	12.0−15.0
Total developmental period (Egg to adult mortality)		36±1.69	33−37.7

Pre-Pupal duration and morphometrics measurement: 3rd instars of matured maggots try to leave the infested fruits and become quiescent before pupation. They become sluggish and stop feeding. At this stage the maggots contracted longitudinally and attained spiral form assuming pre-pupal stage. Total 0.74±0.17 days were required to pass pre-pupal period (Table 1). Length and width of the pre-pupa was varied from 5.3-6.7 mm and 1.7-2.5 mm; mean value being 5.86 ±0.48 mm (Mean± S.D.) and 1.94 ± 0.23mm (Mean± S.D.) respectively (Table 2).

Pupal duration and morphometrics measurement: Total 9.2±0.78 days were required to complete the pupal period (Table 1) and the data range was 8.0-10.0 mm. The pupa measured 5.68± 0.26 mm (Mean± S.D.) in length and 2.39±0.20 mm (Mean± S.D.) in width ;the data range was 5.2-6.0mm for length and 2.1-2.8 mm in width respectively (Table 2).

Depending on temperature and the host, the pupal period may vary from 7 to 13 days (Hollingsworth *et al*., 1997). Gupta and Verma (1995) recorded that the pupal period varied from 7.7 to 9.4 days on bitter gourd, cucumber, and sponge gourd whereas Koul and Bhagat, 1994; Khan *et al*., 1993 observed 6.5 to 21.8 days pupal duration on bottle gourd.

Adult duration: The adult longevity was 14.1±1.28 days (Mean± S.D.) in case of supplying food (10% honey solution) and the data range was 12.0-15.0 mm (Table 1) and when rearing without food the adult longevity was 5.0±0.81 (Mean± S.D.) days and the data range was 4.0-6.0 mm (Table 1).

Morphometrics measurement of adult: In adult male fruit fly abdomen was blunt, ovipositor became absent (Plate 5). They were also smaller in size than that of the females. When reared in bottle gourd, the length of male fruit fly was 6.61±0.59 mm (Mean± S.D.) and the data range was 5.8-7.5mm. The width of male with the wing span was 10.97 ± 0.43 mm (Mean± S.D.) and the data range was 10.2-11.5 mm. (Table 2).

In adult female fruit fly were easily detected by the presence of tapering abdomen extending into an ovipositor (Plate 6). They are comparatively larger than the males. The length and width with the wing expanse of the female adult were observed to vary from 11.5-15.0 mm; mean value being 8.28±0.52 mm (Mean± S.D.) and 13.02±1.28 (Mean± S.D.) respectively (Table 02).

Table 2: Morphometrics measurement of different life stages of cucurbit fruit fly, *B. cucurbitae* on bottle gourd

Life Stage	Size (mm)			
	Length (mm) (Mean± SD)	Data rage	Width (mm) (Mean± SD)	Data range
Larval Instars				
1st Instar	1.1± 0.9	0.49−0.65	0.22 ±0.11	0.20−0.25
2nd Instar	3.03 ± 0.95	3.0−4.0	1.12 ± 0.01	1.0−1.4
3rd Instar	6.42 ± 0.90	5.0−7.8	2.13 ± 0.20	2.0−2.5
Pre-pupal	5.86 ±0.48	5.3−6.7	1.94 ± 0.23	1.7−2.5
Pupal	5.68± 0.26	5.2−6.0	2.39±0.20	2.1−2.8
Adult wing span				
Male	6.61±0.59	5.8−7.5	10.97 ± 0.43	10.2−11.5
Female	8.28±0.52	8.0−9.0	13.02±1.28	11.5−15.0

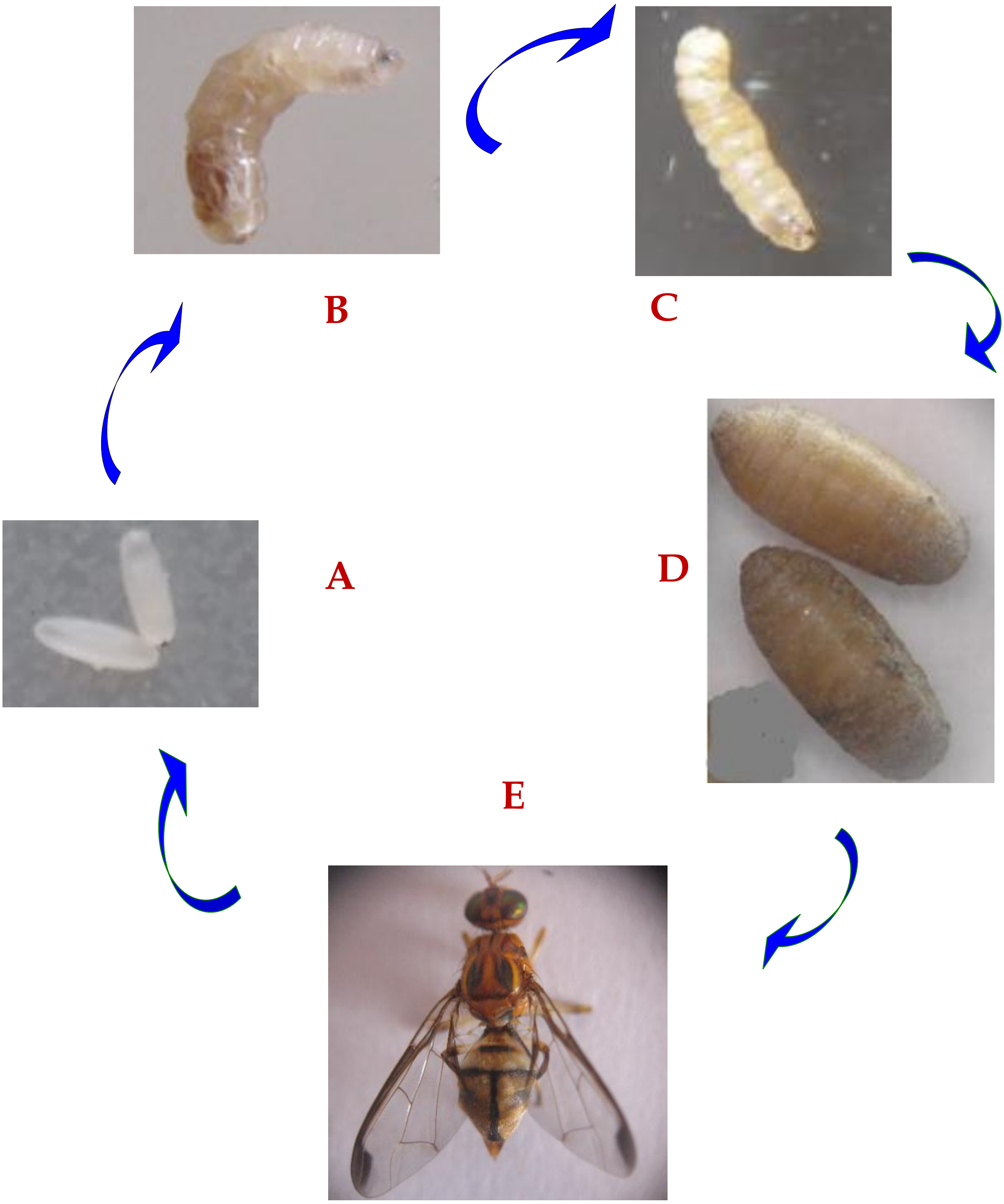

Plate 20: Life cycle of cucurbit fruit fly (*B. cucurbitae*), A. Egg, B. Larva, C. Pre-Pupa, D. Pupa and E. Adult

The total development period (Egg to adult mortality) was 36±1.69 (Mean± S.D.) and the data range was 33.0 - 37.7mm (Table 1).

Finding of the present study are in Corroboration with the earlier works of Lalla and Sinha (1959), Narayanan and Battra (1960), Patel (2007) and Laskar (2013). Minor deviations in Morphometrics may be attributed to the variations in host and environmental conditions.

4.1.2 Larval and Pupal mortality of Cucurbit fruit fly, *B. cucurbitae* during the study period

Larval mortality: During the larval development some natural mortality was found to observe. The larval mortality was mainly due to environmental factors and percent of larval mortality was ranged from 20 to 40% during the study period (Table 03).

Pupal mortality: Pupal mortality was recorded lower than the larval mortality (Figure 02). Most of the healthy pupa formed able to enclose into adult. However, a few numbers not able to enclose into adult which was occurred failure to emerge. Mortality of pupa was noted lower in bottle gourd which was ranged from 10 to 20% during the study period (Table 03).

Table 3: Larval and Pupal mortality of Cucurbit fruit fly, *B. cucurbitae* during the study period

Replications	Released no. of larva	No. of dead larva	Percent of larval mortality	Released no. of pupa	No. of dead pupa	Percent of pupal mortality
Set-I	50	15	30	20	4	20
Set-II	50	20	40	20	2	10
Set-III	50	14	28	20	3	15
Set-IV	50	10	20	20	4	20
Set-V	50	16	32	20	8	40

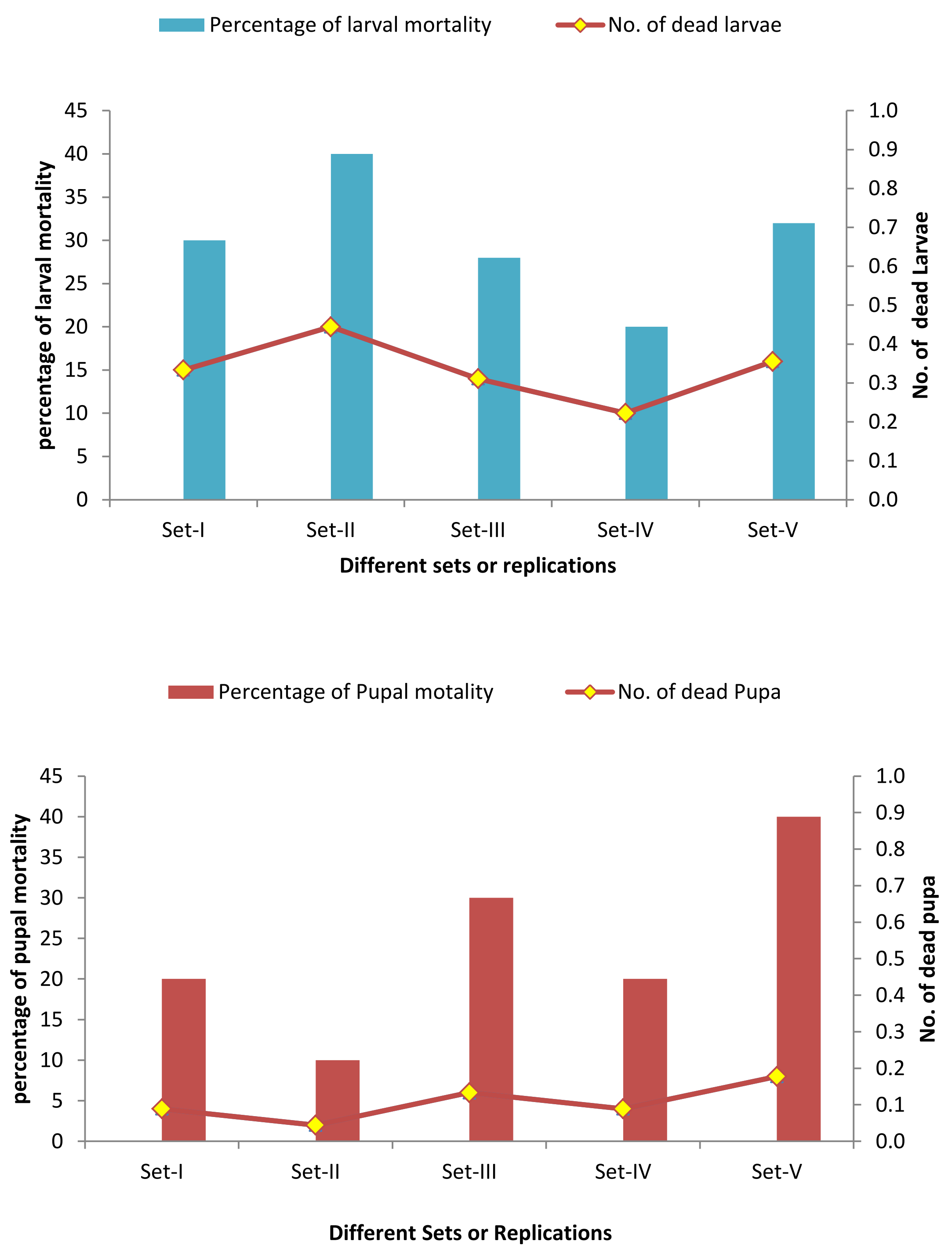

Figure 2: Larval and pupal mortality of *Bactrocera cucurbitae* during the study period

4.1.3 Incidence of cucurbit fruit fly as maggot population in bottle gourd at the different month during the study period

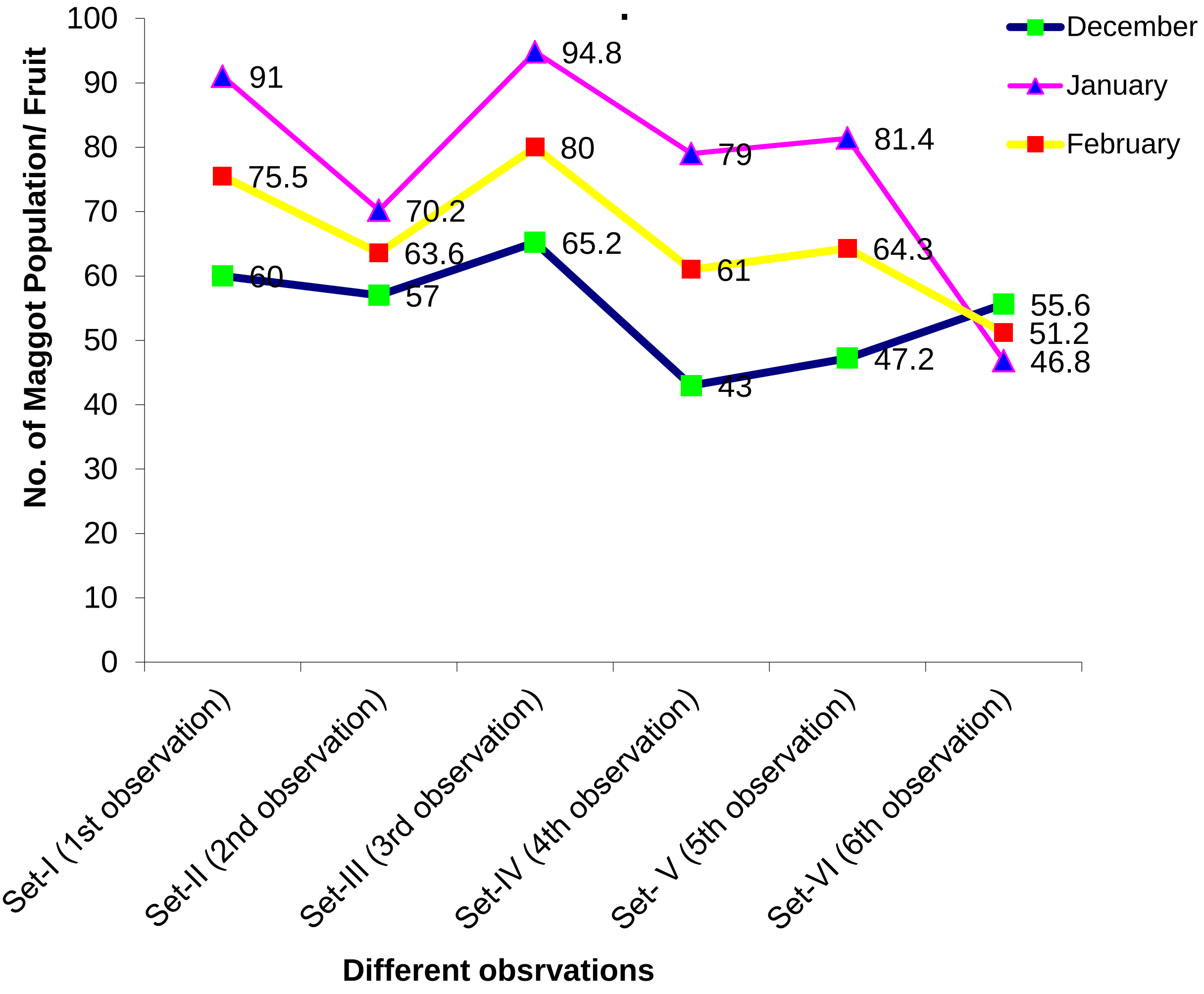

Figure 3: Incidence pattern of cucurbit fruit fly as maggot population in bottle gourd at the different months during the study period

Cucurbit fruit fly, *B. cucurbitae* (Coq.), one of the most important pests of bottle gourd along with all members of family Cucurbitaceae occurred from month of December 1st week to February last week during the study periods. Its infestation was recorded during first week of December and continued till the crop was finally harvested. High larval population (94.8 maggots/fruit) could be recorded from third observation (Each observation was done after 4- 5 days intervals) in the month of January (Figure 3). Population of maggot was relatively low during the study period at the end of each month (December, January and February). Among the different months, the highest maggot populations were observed from month of January, whereas the lowest maggot populations (43) were recorded from 4th observation in the month of December. As a result, the order of incidence pattern of cucurbit fruit fly as maggot population in bottle gourd at the different months during the study period in terms of number were January > February > December. However, population prevalence was of almost of the same order as on each study month from different observations.

No such study was taken up from this region earlier. However, peak population of the pest had been reported to occur on bitter gourd from this region during summer followed by winter season (Banerji *et al.*, 2005). Patnaik *et al.*, (2004) showed that the peak population of the fly could be noted during April-May, i.e., around 18th to 20th standard weeks on bitter gourd. Such infestation on little gourd could be recorded throughout the year starting from the month of February reaching peak during third week of March and with negligible infestation during December-January (Patel & Patel, 1996).

Experiment 2: Efficacy of different traps for the population Management of cucurbit fruit fly, *B. cucurbitae* in vegetable bottle gourd, *Lagenaria siceraria*

4.2.1 Number of captured insects/trap at different days after trap setting at the reproductive stage of bottle gourd

At the different days interval the number of captured insects/trap at the reproductive stage of bottle gourd after trap setting were represented in Table 4. From this table, it was found that, among the different treatments T_5 (Funnel pheromone trap) was showed the best performance in capturing adult cucurbit fruit fly during the study period. At the 5 days after trap setting (DATS), the highest number of fruit fly (6.53) was captured in T_5 (Funnel pheromone trap) treatment, which was significantly different from the all others treatment and followed by 5.87 and 5.40 in T_1 (pheromone trap) and T_3 (Vinegar with rotted fruit trap) respectively; whereas the lowest number of fruit fly (3.07) was captured in T_6 (Sticky board trap) which was closely followed by 3.87 in T_4 (Bait trap with banana mashed) treatment. As a result, the trends of captured adult cucurbit fruit fly in different traps is T_5>T_1>T_3> T_2> T_4 >T_6 at 5 days after trap setting at the reproductive stage of bottle gourd. Similar trend of results were also found from the rest of different days after trap setting at the reproductive stage of bottle gourd, except untreated control treatment T_7 (Table 4).

More or less similar results were also reported by several researchers as Hossen (2012); Akhtaruzzaman *et al*. (2000); Rakshit *et al*. (2011) and Islam (2013). Such as Hossen (2012), who reported that Pheromone trap with funnel + Bait trap was most effective in capturing the adult fruit fly and Pheromone trap with funnel showed the second highest performance. Islam (2013) reported that pheromone trap with bait trap showed the best performance in capturing adult cucurbit fruit fly than Funnel pheromone trap.

Table 4. Number of captured insects/trap at different days after trap setting at the reproductive stage of bottle gourd

Treatments	Number of captured insects/trap at different days after setting of trap									
	5DATS	10 DATS	15 DATS	20 DATS	25 DATS	30 DATS	35 DATS	40 DATS	45 DATS	50 DATS
T_1	5.87 b	5.00 b	4.70 b	3.70 b	2.93 b	2.40 b	2.97 a	2.67 b	2.67 b	1.77 b
T_2	4.47 c	4.20 c	3.60 cd	2.50 d	2.73 bc	1.80 c	2.07 b	2.20 c	2.05 c	1.21 d
T_3	5.40 b	4.87 b	4.10 bc	3.30 c	2.80 bc	2.07 bc	2.37 b	2.65 b	2.07 c	1.50 c
T_4	3.87 d	3.80 c	3.30 d	1.90 e	2.60 c	1.20 d	1.57 c	1.90 d	1.80 d	1.17 d
T_5	6.53 a	5.67 a	5.40 a	4.10 a	3.27 a	3.27 a	3.07 a	3.03 a	2.93 a	2.33 a
T_6	3.07 e	3.00 d	2.10 e	1.30 f	1.10 d	1.00 d	1.07 d	1.00 e	1.10 e	0.70 e
T_7	--	--	--	--	--	--	--	--	--	--
$LSD_{(0.05)}$	0.508	0.450	0.595	0.390	0.293	0.531	0.308	0.180	0.233	0.138
Level of significance	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CV(%)	6.23	5.94	8.50	7.75	6.37	8.34	7.92	6.83	9.09	7.56

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability; Values are the means of three replications

[T_1: Pheromone trap; T_2: Bait trap with sweet gourd mashed; T_3: Vinegar with rotted fruit trap; T_4: Bait trap with banana mashed; T_5: Funnel pheromone trap; T_6: Sticky board trap and T_7: Untreated control]

4.2.1.2 Efficacy of different traps on the number of captured insects/trap at the different reproductive stages of bottle gourd

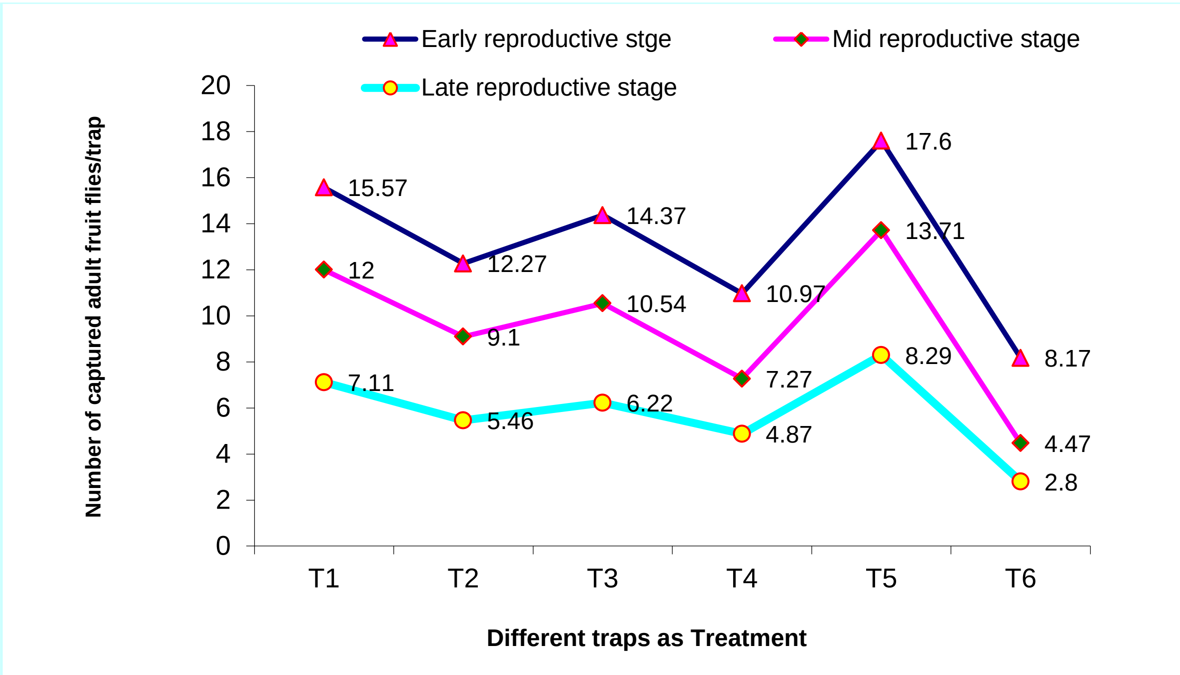

Figure 4: Efficacy of different traps on the no. of captured insects/trap at the early, mid and late reproductive stages of bottle gourd

At the early, mid and late reproductive stages of bottle gourd, the number of adult fruit fly captured/trap in the different traps shown in Figure 4. The graph expressed that T_5 (Funnel pheromone trap) showed the best performance in capturing adult fruit fly during the study period. The highest number of captured fruit fly/trap (17.6) was observed from T_5 (Funnel pheromone trap); almost same level of adult fruit fly was caught in T_1 (Pheromone trap) treatment by 15.57, whereas the lowest number of captured fruit fly/trap (8.17) was recorded from T_6 (Sticky board trap). Similar trends of adult fruit fly captured in different traps at mid and late reproductive stages of bottle gourd during the study period (Figure 4).

4.2.2 Efficacy of different traps against cucurbit fruits fly, *B. cucurbitae* on the basis of healthy and infested fruits by number and fruit infestation of bottle gourd

4.2.2.1 At the early reproductive stage of bottle gourd

At the early reproductive stage of bottle gourd, the consequence of different traps on the number of healthy fruits/plot as been shown in Table 5. From this table it was revealed that, the highest number of healthy fruits/plot (9.73) was recorded from T_5 (Funnel pheromone trap) closely followed by 9.20 in T_1 (Pheromone trap) treatment, whereas the lowest number of healthy fruits/plot (6.67) was recorded from T_7 (Untreated control) treatment.

In case of number of infested fruits/plot at the early reproductive stage of bottle gourd, the highest number of infested fruits/plot were collected from T_7 (Untreated control) which was statistically similar by T_6 (Sticky board trap), on the other hand, the lowest number of infested fruits/plot were collected from T_5 (Funnel pheromone trap) which was closely followed by 0.33 in T_1 (Pheromone trap) and T_3 (Vinegar with rotted fruit trap) treatment (Table 5).

In the same way, the lowest percent of infestation (2.67) were observed from T_5 (Funnel pheromone trap) treatment which was closely followed by 3.50 and 3.61 in T_1 (Pheromone trap) and T_3 (Vinegar with rotted fruit trap) treatment respectively. On the other hand, the highest percent of infestation (10.65) were observed from T_7 (Untreated control) which was closely followed by 7.45 in T_6 (Sticky board trap), 6.14 in T_4 (Bait trap with banana mashed) treatment.

From the results in table 5 showed significant variations due to the effect of different traps on percent of reduction of *B. cucurbitae* at the early reproductive stage of bottle gourd.

Among different traps, T_5 (Funnel pheromone trap) showed more reduction (74.93%) of infestation due to cucurbit fruit fly and supported to make sure the more yield of bottle gourd.

In the similar trend, T_6 (Sticky board trap), showed lower performance to control cucurbit fruit fly while minimum reduction (30.05%) was recorded on bottle gourd (Table 5). As a result, the order of efficacy of different traps in terms of fruit infestation reduction at early reproductive stage is $T_5 > T_1 > T_3 > T_2 > T_4 > T_6 > T_7$

Table 5. Efficacies of different traps against cucurbit fruits fly on the basis of infested fruits and fruit infestation by number at early reproductive stage of bottle gourd

Treatments	Number of fruits/plot		% Infestation	Infestation reduction over control (%)
	Healthy fruits (No.)	Infested fruits (No.)		
T_1	9.20 bc	0.33 cd	3.50 d	67.14
T_2	8.67 d	0.40 bcd	4.42 cd	58.50
T_3	8.87 cd	0.33 cd	3.61 d	66.10
T_4	8.13 e	0.53 bc	6.14 bc	42.35
T_5	9.73 a	0.27 d	2.67 d	74.93
T_6	7.47 f	0.60 ab	7.45 b	30.05
T_7	6.67 g	0.80 a	10.65 a	--
$LSD_{(0.05)}$	0.468	0.205	2.209	--
Level of significance	0.01	0.01	0.01	--
CV(%)	4.22	12.17	15.02	--

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability. Values are the means of three replications

[T_1: Pheromone trap; T_2: Bait trap with sweet gourd mashed; T_3: Vinegar with rotted fruit trap; T_4: Bait trap with banana mashed; T_5: Funnel pheromone trap; T_6: Sticky board trap and T_7: Untreated control]

4.2.2.2 At the mid fruiting stage

At the mid reproductive stage of bottle gourd, the consequence of different traps on the number healthy fruits/plot as been shown in Table 6. From this table it was revealed that, the highest number of healthy fruits/plot (11.67) was harvested from T_5 (Funnel pheromone trap) which was closely followed by 11.07 in T_1 (Pheromone trap) treatment, whereas the lowest number of healthy fruits/plot (7.67) was harvested from T_7 (Untreated control) treatment which was closely followed by 8.33 in T_6 (Sticky board trap).

In case of number of infested fruits/plot at the mid reproductive stage of bottle gourd, the highest number of infested fruits/plot were collected from T_7 (Untreated control) by 0.87 which was statistically similar by 0.80 in T_6 (Sticky board trap) and closely followed by 0.73 in T_4: Bait trap with banana mashed, on the other hand, the lowest number of infested fruits/plot were collected from T_5 (Funnel pheromone trap) by 0.27 which was closely followed by 0.40 in T_1 (Pheromone trap) treatment (Table 6).

In the same way, the lowest percent of infestation (2.22) were observed from T_5 (Funnel pheromone trap) and closely followed by 3.49 in T_1 (Pheromone trap); closely followed in T_3 (Vinegar with rotted fruit trap) treatments. On the other hand, the highest percent of infestation (10.15) were observed from T_7 (Untreated control) which was closely followed by 8.77 in T_6 (Sticky board trap) treatment (Table 6).

At the mid reproductive stage of bottle gourd, considering the reduction of fruit infestation, from the results in table 6 showed significant variations due to the effect of different traps on percent of reduction of *B. cucurbitae*. Among different traps, T_5 (Funnel pheromone trap) showed more reduction (78.13%) of infestation due to cucurbit fruit fly and supported to make sure the more yield of bottle gourd and second highest infestation reduction were observed in T_1 (Pheromone trap).

In the similar trend, T_6 (Sticky board trap), showed lower performance to control cucurbit fruit fly while minimum reduction (13.60%) was recorded on bottle gourd. As a result, the order of efficacy of different traps in terms of fruit infestation reduction at mid reproductive stage is $T_5 > T_1 > T_3 > T_2 > T_4 > T_6 > T_7$ (Table 6).

Table 6. Efficacies of different traps against cucurbit fruits fly on the basis of infested fruits and fruit infestation by number at mid reproductive stage of bottle gourd

Treatments	Number of fruits/plot		% Infestation	Infestation reduction over control (%)
	Healthy fruits (No.)	Infested fruits (No.)		
T_1	11.07 b	0.40 def	3.49 efg	65.62
T_2	10.27 d	0.53 cd	4.93 de	51.43
T_3	10.73 c	0.47 cde	4.16 ef	59.01
T_4	9.27 f	0.73 ab	7.31 bc	27.98
T_5	11.67 a	0.27 f	2.22 g	78.13
T_6	8.33 g	0.80 a	8.77 ab	13.60
T_7	7.67 h	0.87 a	10.15 a	--
$LSD_{(0.05)}$	0.319	0.164	1.516	--
Level of significance	0.01	0.01		--
CV(%)	4.85	17.49	15.87	--

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability. Values are the means of three replications

[T_1: Pheromone trap; T_2: Bait trap with sweet gourd mashed; T_3: Vinegar with rotted fruit trap; T_4: Bait trap with banana mashed; T_5: Funnel pheromone trap; T_6: Sticky board trap and T_7: Untreated control]

4.2.2.3 At the late reproductive stage of bottle gourd

At the late reproductive stage of bottle gourd, the consequence of different traps on the number healthy fruits/plot has been shown in Table 7. From this table it was revealed that, the highest number of healthy fruits/plot (10.27) was recorded from T_5 (Funnel pheromone trap) and closely followed by 10.07 in T_1 (Pheromone trap) treatment, whereas the lowest number of healthy fruits/plot (7.40) was recorded from T_7 (Untreated control) treatment which was closely followed by 8.20 in T_6 (Sticky board trap).

In case of number of infested fruits/plot at the late reproductive stage of bottle gourd, the highest number of infested fruits/plot were collected from T_7 (Untreated control) by 1.00 which was statistically similar by 0.87 in T_6 (Sticky board trap), on the other hand, the lowest number of infested fruits/plot were collected from T_5 (Funnel pheromone trap) by 0.33 which was closely followed by 0.40 in T1 (Pheromone trap) and T_3 (Vinegar with rotted fruit trap) treatment (Table 7).

In the same way, the lowest percent of infestation (3.13 and 3.82) were observed from T_5 (Funnel pheromone trap) and T_1 (Pheromone trap) treatments respectively. On the other hand, the highest percent of infestation (11.92) were observed from T_7 (Untreated control) which was closely followed by 9.57 in T_6 (Sticky board trap) treatment (Table 7). As a result, the order of efficacy of different traps in terms of reducing fruit infestation at late reproductive stage is $T_5 > T_1 > T_3 > T_2 > T_4 > T_6 > T_{7.}$

Considering the reduction of fruit infestation, from the results in table 7 showed significant variations due to the effect of different traps on percent of reduction of *B. cucurbitae* at the late reproductive stage of bottle gourd. Among different traps, T_5 (Funnel pheromone trap) showed more reduction (73.74%) of infestation due to cucurbit fruit fly and supported to make sure the more yield of bottle gourd.

In the similar trend, T_6 (Sticky board trap), showed lower performance to control cucurbit fruit fly while minimum reduction (19.71%) was recorded on bottle gourd (Table 7). As a result, the order of efficacy of different traps in terms of fruit infestation reduction at late reproductive stage is $T_5 > T_1 > T_3 > T_2 > T_4 > T_6 > T_7$.

Table 7. Efficacy of different traps against cucurbit fruits flies on the basis of infested fruits and fruit infestation by number at late reproductive stage of bottle gourd

Treatments	Number of fruits/plot		% Infestation	Infestation reduction over control (%)
	Healthy fruits (No.)	Infested fruits (No.)		
T_1	10.07 ab	0.40 ef	3.82 e	67.95
T_2	9.20 d	0.60 cd	6.12 d	48.66
T_3	9.67 c	0.53 de	5.23 d	56.12
T_4	8.60 e	0.80 b	8.51 bc	28.61
T_5	10.27 a	0.33 f	3.13 e	73.74
T_6	8.20 f	0.87 ab	9.57 b	19.71
T_7	7.40 g	1.00 a	11.92 a	--
$LSD_{(0.05)}$	0.367	0.134	1.326	--
Level of significance	0.01	0.01	0.01	--
CV(%)	5.34	12.23	11.51	--

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability. Values are the means of three replications

[T_1: Pheromone trap; T_2: Bait trap with sweet gourd mashed; T_3: Vinegar with rotted fruit trap; T_4: Bait trap with banana mashed; T_5: Funnel pheromone trap; T_6: Sticky board trap and T_7: Untreated control]

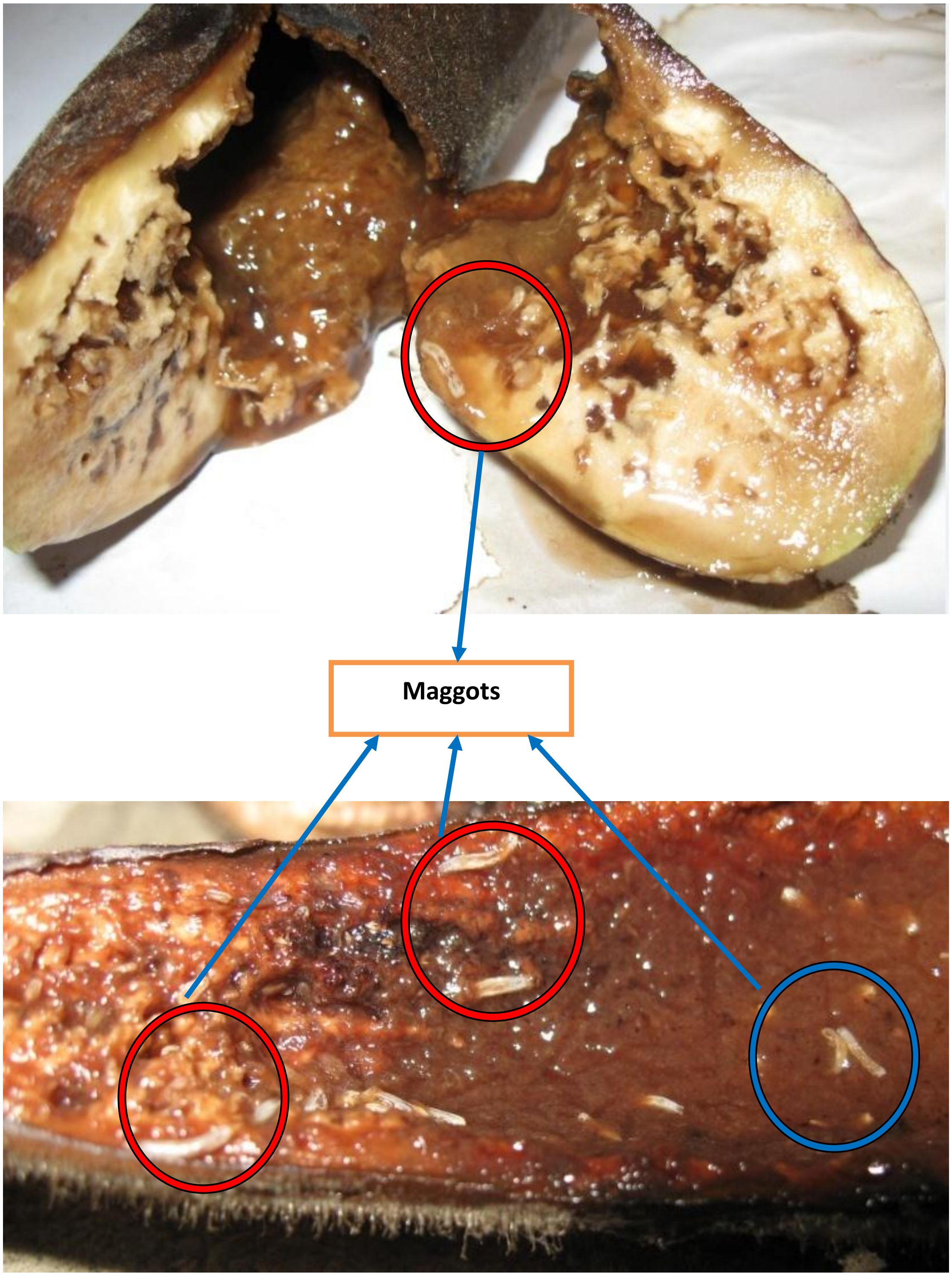

Plate 21: Completely rotted infested fruits of bottle gourd with maggot due to *B. cucurbitae*

4.2.3 Efficacy of different traps against cucurbit fruits fly, *B. cucurbitae* on the basis of healthy and infested fruits by weight and fruit infestation at the reproductive stage of bottle gourd

4.2.3.1 At the early reproductive stage of bottle gourd

At the early reproductive stage of bottle gourd, the consequence of different traps on the weight of healthy fruits/plot as been shown in Table 8. From this table it was revealed that, the highest weight of healthy fruits/plot (24.60 kg) was recorded from T_5 (Funnel pheromone trap) closely followed by 23.47 kg in T_1 (Pheromone trap) treatment, whereas the lowest number of healthy fruits/plot (17.60 kg) was recorded from T_7 (Untreated control) treatment.

In case of weight of infested fruits/plot and percent of infestation at the early reproductive stage of bottle gourd, the highest weight of infested fruits/plot (2.12 kg) were harvested from T_7 (Untreated control) which was statistically similar by 2.00 kg in T_6 (Sticky board trap), whereas, the lowest weight of infested fruits/plot (1.13 kg) were collected from T_5 (Funnel pheromone trap) which was closely followed by 1.47 kg in T_1 (Pheromone trap) treatment. On the other hand, the lowest percent of infestation (4.40) were observed from T_5 (Funnel pheromone trap) treatment which was closely followed by 5.88 in T_1 (Pheromone trap). In the same way, the highest percent of infestation (10.53) were observed from T_7 (Untreated control) which was closely followed by 9.36 in T_6 (Sticky board trap) treatment (Table 8).

From the results in table 8 showed significant variations due to the effect of different traps on percent infestation of reduction over control of bottle gourd at the early reproductive stage. Among different traps, T_5 (Funnel pheromone trap) showed more reduction (58.21%)

of infestation due to cucurbit fruit fly and supported to make sure the more yield of bottle gourd.

In the similar trend, T_6 (Sticky board trap), showed lower performance to control cucurbit fruit fly while minimum reduction (11.11%) was recorded on bottle gourd (Table 8). As a result, the order of efficacy of different traps in terms of fruit infestation reduction by weight at early reproductive stage is T_5> T_1 and T_2> T_3> T4> T_6> T_7.

Table 8. Efficacies of different traps against cucurbit fruits fly on the basis of infested fruits and fruit infestation by weight at early reproductive stage of bottle gourd

Treatments	Weight of fruits/plant		% Infestation	Infestation reduction over control (%)
	Healthy fruit (kg)	Infested fruit (kg)		
T_1	23.47 ab	1.47 d	5.88 d	44.16
T_2	21.53 cd	1.73 bc	7.45 c	44.16
T_3	21.87 bc	1.40 d	6.02 d	42.83
T_4	20.07 de	1.87 bc	8.51 bc	19.18
T_5	24.60 a	1.13 e	4.40 e	58.21
T_6	19.40 e	2.00 ab	9.36 b	11.11
T_7	17.60 f	2.12 a	10.53 a	--
$LSD_{(0.05)}$	1.69	0.18	1.10	--
Level of significance	0.05	0.05	0.05	--
CV(%)	4.86	5.32	6.93	--

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability. Values are the means of three replications

[T_1: Pheromone trap; T_2: Bait trap with sweet gourd mashed; T_3: Vinegar with rotted fruit trap; T_4: Bait trap with banana mashed; T_5: Funnel pheromone trap; T_6: Sticky board trap and T_7: Untreated control]

4.2.3.2 At the mid reproductive stage of bottle gourd

At the mid reproductive stage of bottle gourd, the consequence of different traps on the weight of healthy fruits/plot has been represented in Table 9. From this table it was observed that, the highest weight of healthy fruits/plot (34.60 kg) was recorded from T_5 (Funnel pheromone trap) closely followed by 32.20 kg and 31.87 in T_1 (Pheromone trap) and T_3 (Vinegar with rotted fruit trap) treatments respectively, whereas the lowest weight of healthy fruits/plot (25.80 kg) was harvested from T_7 (Untreated control) treatment which were followed with 28.40 in T_6 (Sticky board trap) treatment.

Accordingly weight of infested fruits/plot and percent of infestation at the early reproductive stage of bottle gourd, the highest weight of infested fruits/plot (5.00 kg) were harvested from T_7 (Untreated control) which was statistically similar by 4.20 kg in T_6 (Sticky board trap), whereas, the lowest weight of infested fruits/plot (2.20 kg) were collected from T_5 (Funnel pheromone trap) which was closely followed by 2.60 kg in T_1 (Pheromone trap) treatment. On the other hand, the lowest percent of infestation (5.97) were observed from T_5 (Funnel pheromone trap) treatment which was closely followed by 7.48 in T_1 (Pheromone trap). In the same way, the highest percent of infestation (16.24) were observed from T_7 (Untreated control) which was closely followed by 12.88 in T_6 (Sticky board trap) treatment (Table 9).

From the results in table 9 showed significant variations due to the effect of different traps on percent infestation of reduction over control of bottle gourd at the mid reproductive stage. Among different traps, T_5 (Funnel pheromone trap) showed more reduction (63.24%)

of infestation due to cucurbit fruit fly and supported to make sure the more yield of bottle gourd.

Table 9. Efficacies of different traps against cucurbit fruits fly on the basis of infested fruits and fruit infestation by weight at mid reproductive stage of bottle gourd

Treatments	Weight of fruits/plant		% Infestation	Infestation reduction over control (%)
	Healthy fruit (kg)	Infested fruit (kg)		
T_1	32.20 ab	2.60 f	7.48 g	53.94
T_2	30.20 bc	3.80 c	11.18 d	53.94
T_3	31.87 ab	3.00 e	8.61 f	46.98
T_4	30.07 bc	3.40 d	10.16 e	37.44
T_5	34.60 a	2.20 g	5.97 h	63.24
T_6	28.40 cd	4.20 b	12.88 c	20.69
T_7	25.80 de	5.00 a	16.24 a	--
$LSD_{(0.05)}$	3.04	0.40	0.64	--
Level of significance	0.05	0.05	0.01	--
CV(%)	6.14	5.55	4.90	--

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability. Values are the means of three replications

[T_1: Pheromone trap; T_2: Bait trap with sweet gourd mashed; T_3: Vinegar with rotted fruit trap; T_4: Bait trap with banana mashed; T_5: Funnel pheromone trap; T_6: Sticky board trap and T_7: Untreated control]

On the other hand, T_6 (Sticky board trap), showed lower performance to control cucurbit fruit fly while minimum reduction (20.69%) was recorded on bottle gourd.

Similar trend of results were also observed at the late reproductive stage of bottle gourd on the basis of healthy fruits, infested fruits and fruit infestation by weight from Table 10.

As a result, the order of efficacy of different traps in terms of fruit infestation reduction by weight at mid and late reproductive stage of bottle gourd is $T_5 > T_1 > T_3 > T_2 > T_4 > T_6 > T_7$.

Table 10. Efficacies of different traps against cucurbit fruits fly on the basis of infested fruits and fruit infestation by weight at late reproductive stage of bottle gourd

Treatments	Weight of fruits/plant		% Infestation	Infestation reduction over control (%)
	Healthy fruit (kg)	Infested fruit (kg)		
T_1	30.80 b	2.53 d	7.64 e	47.46
T_2	28.20 c	2.87 cd	9.24 d	47.46
T_3	30.60 b	2.13 e	6.52 e	55.16
T_4	27.80 c	3.20 bc	10.32 cd	29.02
T_5	33.20 a	1.80 e	5.13 f	64.72
T_6	26.20 c	3.40 ab	11.50 c	20.91
T_7	21.20 e	3.60 a	14.54 a	--
$LSD_{(0.05)}$	2.21	0.33	1.22	--
Level of significance	0.05	0.01	0.05	--
CV(%)	4.82	5.80	6.19	--

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability. Values are the means of three replications

[T_1: Pheromone trap; T_2: Bait trap with sweet gourd mashed; T_3: Vinegar with rotted fruit trap; T_4: Bait trap with banana mashed; T_5: Funnel pheromone trap; T_6: Sticky board trap and T_7: Untreated control]

4.2.4 Effect of different traps against cucurbit fruit fly and its impact on yield contributing characters of bottle gourd, *Lagenaria siceraria*

Length of fruit: The impact of different traps on length of healthy fruits of bottle gourd has been shown in Table 11. Significant variations were observed among the treatments in terms of length of healthy fruits. The highest length of single fruit (55.91cm) was recorded in T_5 (Funnel Pheromone trap) which was statistically similar with 55.27cm in

T_1(Pheromone trap), 54.21cm in T_3 (Vinegar with rotted fruit trap), 53.52cm in T_2 (Bait trap with sweet gourd mashed) and followed by 51.08cm in T_4 (Bait trap with banana mashed). On the other hand the lowest length of bottle gourd was 45.39 cm in T_7 (Untreated control), which was statistically similar with 48.68 cm in T_6 (Sticky board trap) treatment.

From the above finding it was observed that, T_5 (funnel pheromone trap) treatment was showed the best performance for the length of bottle gourd.

Girth of fruit: The impact of different traps on Girth of healthy fruits of bottle gourd has been shown in Table 11. Significant variations were observed among the treatments in terms of girth of healthy fruits. The highest girth of single fruit (25.0 cm) was recorded in T_5 (Funnel Pheromone trap) which was statistically similar with 24.55 cm in T_1 (Pheromone trap) and closely followed by 22.97cm and 22.28 in T_3 (Vinegar with rotted fruit trap) and in T_2 (Bait trap with sweet gourd mashed) treatments respectively. On the other hand, the lowest girth of bottle gourd was 20.97 cm recorded in T_7 (Untreated control) which was statistically similar with 21.11 cm in T_6 (Sticky board trap) and followed by 21.86 cm in T_4 (Bait trap with banana mashed) treatment (Table 11).

From the above finding it was observed that the highest bottle gourd girth was found in T_5 funnel pheromone trap.

Single fruit weight: The impact of different traps on single fruit weight of healthy fruits of bottle gourd has been shown in Table 11. Significant variations were observed among the treatments in terms of single fruit weight of healthy fruits. From this table, it was revealed that the highest single fruit weight was (2.95 kg) recorded in T_5 (Funnel Pheromone trap) which was statistically similar with 2.85 kg in T_1 (Pheromone trap) treatment. On the other hand the lowest single fruit weight was 1.90kg recorded in T_7 (Untreated control) which was statistically similar with 1.95kg in T_6 (Sticky board trap) followed by 2.20 in T_4 (Bait trap with banana mashed) treatment.

Table 11. Effect of different traps against cucurbit fruit fly and its impact on yield contributing characters of bottle gourd, *Lagenaria siceraria*

Treatments	Length of single fruit (cm)	Girth of single fruit (cm)	Single fruit weight (kg)
T_1	55.27 ab	24.55 ab	2.85 ab
T_2	53.52 ab	22.28 abc	2.35 c
T_3	54.21 ab	22.97 abc	2.65 b
T_4	51.08 abc	21.86 bc	2.20 cd
T_5	55.91 a	25.00 a	2.95 a
T_6	48.68 bc	21.11 c	1.95 de
T_7	45.39 c	20.97 c	1.90 e
$LSD_{(0.05)}$	6.134	2.696	0.246
Level of significance	0.01	0.05	0.01
CV(%)	6.73	7.72	7.37

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability. Values are the means of three replications

[T_1: Pheromone trap; T_2: Bait trap with sweet gourd mashed; T_3: Vinegar with rotted fruit trap; T_4: Bait trap with banana mashed; T_5: Funnel pheromone trap; T_6: Sticky board trap and T_7: Untreated control]

4.2.5 Effect of different traps against cucurbit fruit fly in bottle gourd on the basis of yield/ha during total cropping season

4.2.5.1 On the basis healthy fruits yield by weight during total cropping season

Significant variation was observed in terms of healthy fruit yield and increase of healthy fruit yield over control at the total cropping season of bottle gourd. Result showed that the highest yield of healthy fruits (69.96 t/ha) was observed in T_5 (Funnel Pheromone trap) treatment which was closely followed by 66.89 t/ha in T_1 (Pheromone trap); 65.14 t/ha in T_3 (Vinegar with rotted fruit trap) treatment, whereas the lowest yield of healthy fruits (57.32 t/ha) was observed in untreated control (T_7) treatment which was followed by 60.74 t/ha and 63.91 t/ha in T_6 (Sticky board trap) and in T_4 (Bait trap with banana mashed) treatments respectively. In the same way, the per cent increase of healthy fruit yield over control during the cropping season of bottle gourd was 18.07% in treatment T_5 (Funnel Pheromone trap) followed by 14.31% in T_1 (Pheromone trap). The transitional per cent increase of yield over control was recorded in T_3 (14.31%) treatment (Table 12).

4.2.5.2 On the basis infested fruits yield by weight during total cropping season

From table 12, significant variation was observed in terms of infested fruit yield and decrease of infested fruit yield over control at the total cropping season of bottle gourd. Result showed that the highest yield of infested fruits (25.71 t/ha) was observed in untreated control (T_7) treatment which was closely followed by 24.64 t/ha in T_6 (Sticky board trap) treatment, whereas the lowest yield of infested fruits (19.45 t/ha) was observed in T_5 (Funnel Pheromone trap) treatment which was followed by 21.38 t/ha in T_1 (Pheromone trap); 22.50 t/ha and in T_2 (Bait trap with sweet gourd mashed) and 22.44 t/ha in T_3 (Vinegar with rotted fruit trap) treatments respectively. Similarly, the per cent decrease of infested fruit yield over control during the cropping season of bottle gourd was 32.19% in treatment T_5 (Funnel Pheromone trap) followed by 20.25% in T_1 (Pheromone trap). The transitional per cent decrease of yield over control was recorded in T_2 (14.27%) treatment.

Table 12. Effect of different traps against cucurbit fruit fly in bottle gourd on the basis of yield/ha during total cropping season

Treatments	Healthy fruit yield (t/ha)	Percent increase over control	Infested fruit yield (t/ha)	Percent decrease over control
T_1	66.89 ab	14.31	21.38 d	20.25
T_2	64.35 abc	10.92	22.50 cd	14.27
T_3	65.14 ab	12.00	22.44 cd	0.73
T_4	63.91 abc	10.31	23.69 bc	0.48
T_5	69.96 a	18.07	19.45 e	32.19
T_6	60.74 bc	5.97	24.64 ab	0.26
T_7	57.32 c	--	25.71 a	--
$LSD_{(0.05)}$	6.868	--	1.705	--
Level of significance	0.05	--	0.01	--
CV(%)	6.54	--	5.14	--

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability. Values are the means of three replications

[T_1: Pheromone trap; T_2: Bait trap with sweet gourd mashed; T_3: Vinegar with rotted fruit trap; T_4: Bait trap with banana mashed; T_5: Funnel pheromone trap; T_6: Sticky board trap and T_7: Untreated control]

4.2.6.1 Relationship between number of captured fruit fly and percent of fruit infestation among different traps:

Correlation study was done to establish the relationship between number of captured fruit fly and percent of fruit infestation among different traps. From the Figure 5, it was revealed that negative correlation was observed between the parameters. It was evident that the equation y = - 0.519x + 11.46 gave a good fit to the data and the co-efficient of determination (R^2 = 0.943) fitted regression line had a significant regression co-efficient. It may be concluded from the figure that the percent of fruit infestation was strongly as well as negatively correlated with number of captured fruit fly/trap. Percent of fruit infestation /treated plot was decreased due to increase of the number of captured fruit fly/trap.

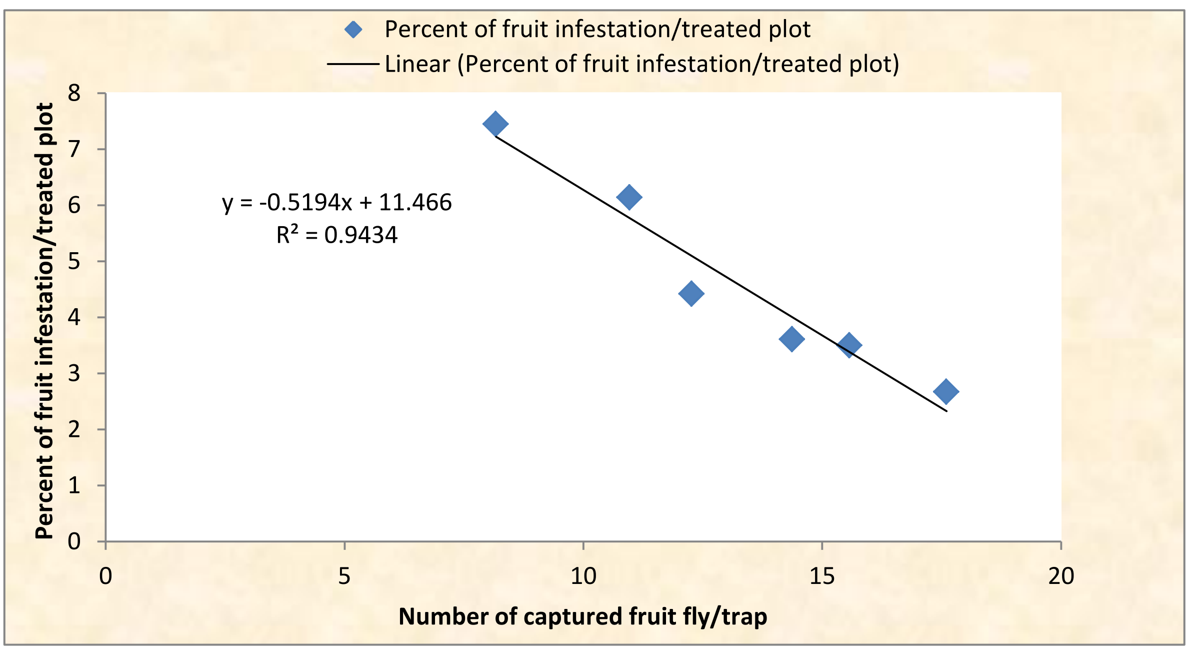

Figure 5: Relationship between number of captured fruit fly and percent of fruit infestation among different traps

4.2.6.2 Relationship between number of captured fruit fly and percent of fruit infestation among different traps:

Correlation study was done to establish the relationship between number of captured fruit fly and Healthy fruit yield (ton/ha) among different traps. From the Figure 6, it was revealed that positive correlation was observed between the parameters. It was evident that the equation y = = 0.886x + 53.49 gave a good fit to the data and the co-efficient of determination (R^2 = 0.945) fitted regression line had a significant regression co-efficient. It may be concluded from the figure that the Healthy fruit yield was strongly as well as positively correlated with number of captured fruit fly/trap. Healthy fruit yield (ton/ha) was increased due to increase of the number of captured fruit fly/trap.

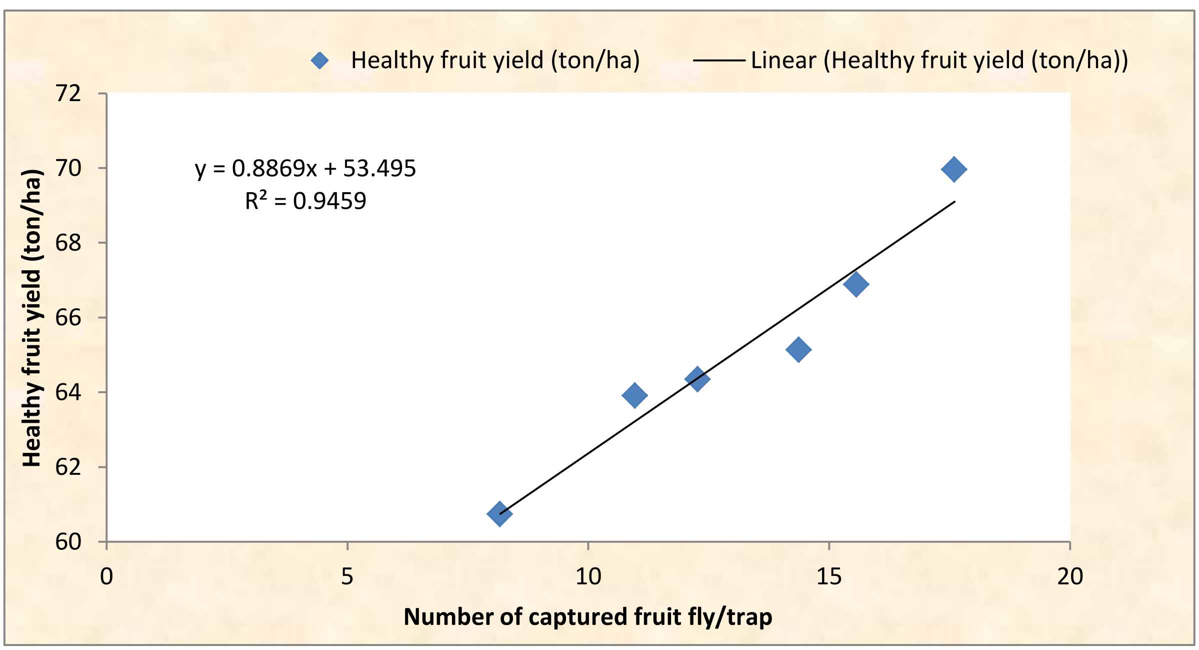

Figure 6: Relationship between number of captured fruit fly and healthy fruit yield among different traps

4.2.6.3 Relationship between percent of fruit infestation and healthy fruit yield among different traps:

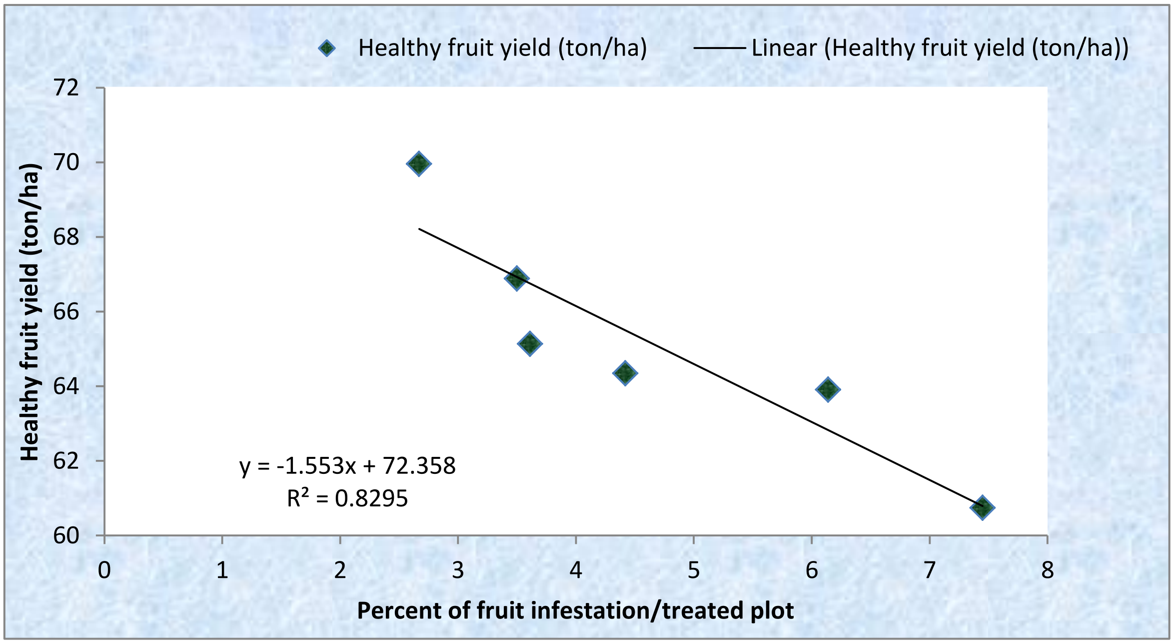

Figure 7: Relationship between percent of fruit infestation/treated plot and healthy fruit yield (ton/ha) among different traps

Correlation study was done to establish the relationship between percent of fruit infestation/treated plot and healthy fruit yield (ton/ha) among different traps. From the Figure 7, it was revealed that positive correlation was observed between the parameters. It was evident that the equation y = = -1.553x + 72.35 gave a good fit to the data and the co-efficient of determination (r^2 = 0.829) fitted regression line had a significant regression co-efficient. It may be concluded from the figure that the healthy fruit yield was strongly as well as negatively correlated with percent of fruit infestation/treated plot. Healthy fruit yield (ton/ha) was decreased due to increase of the percent of fruit infestation/treated plot.

4.2.6.4 Relationship between healthy fruit yield and single fruit weight among different traps:

Correlation study was done to establish the relationship between single fruit weight and Healthy fruit yield (ton/ha) among different traps. From the Figure 8, it was revealed that positive correlation was observed between the parameters. It was evident that the equation y = = 9.1031x + 42.132 gave a good fit to the data and the co-efficient of determination (R^2 = 0.8754) fitted regression line had a significant regression co-efficient. It may be concluded from the figure that the healthy fruit yield was strongly as well as positively correlated with single fruit weight. Healthy fruit yield (ton/ha) was increased due to increase of the single fruit weight.

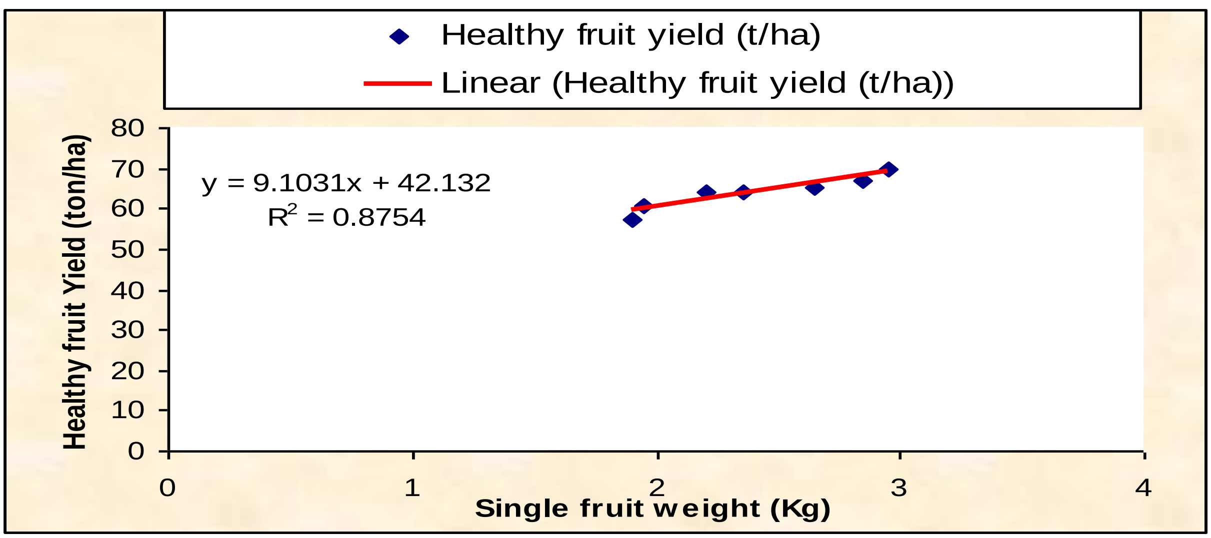

Figure 8: Relationship between single fruit weight and healthy fruit yield (ton/ha) among different traps

CHAPTER V

SUMMARY AND CONCLUSION

Two studies were undertaken to study biology of cucurbit fruit fly, *Bactrocera cucurbitae* and roles of different traps for their controlling to produce safe cucurbit vegetables in Bangladesh at the laboratory of the Department of Entomology and central farm of Sher-e-Bangla Agricultural University, Dhaka during October, 2016 to March 2017. The components of the study conclude the biology of the cucurbit fruit fly, *Bactrocera cucurbitae* in the laboratory and roles of different traps for *B. cucurbitae* controlling.

Incase of the study biology, infested bottle gourd fruits were collected from research field of Sher-e-Bangla Agricultural University farm for ensuring supply of fresh eggs and maggots for the study biology and rearing of *B. cucurbitae* was done in a rearing chamber and the experiment was laid out in Complete Randomized Design.

The treatments of the management were T_1 = Pheromone Trap, T_2 = Bait trap with sweet gourd mashed, T_3 = Vinegar with rotted fruit trap, T_4 = Bait trap with banana mashed, T_5 = Funnel pheromone Trap, T_6 = Sticky board trap, T_7 = Untreated control and laid out in a Randomized Complete Block Design (RCBD) with three replications. The whole reproductive period of bottle gourd was divided into three stages viz., early, mid and late reproductive stages. Data were collected on number of fruit and weight of fruits/plot at early, mid and late reproductive stage, total yield and presence of cucurbit fruit fly at different reproductive stage. Healthy fruits/plot, infested fruits/plot, per cent fruit infestation, per cent increase over control and percent decrease over control was considered at each of the stage.

Results indicated that the period of incubation, larvae (1^{st}, 2^{nd} and 3^{rd} instars), pre-pupae and pupae of cucurbit fruit fly, *B. cucurbitae* were 1.69±0.28, 1.72±0.33, 1.41±0.31, 2.31±0.51, 0.74±0.17 and 9.2±0.78 days respectively. Adult longevity of *B. cucurbitae* with food and without food was 14.1±1.28 and 5.0±0.81 days, respectively. The total life span /Total developmental period (Egg to adult mortality) of *B. cucurbitae* was 36±1.69 days and data ranged was 33−37.7 during the study period.

The morphometric measurements of different stages of the *B. cucurbitae* were measured. Data on larvae mortality; pupae mortality and Incidence of cucurbit fruit fly as maggot population in bottle gourd at the different month during the study period were also recorded during the study period. Such as the highest maggot population /fruit were observed in the month of January during the study period. Despite the fact that it was not possible to assess the roles of all the different factors separately which influence the population development of the *B. cucurbitae.*

In the study efficacy of different traps for their controlling to produce safe cucurbit vegetables was indicated the Funnel pheromone trap (T_5) showed the best performances for controlling of the *B. cucurbitae* among all the traps. The results revealed from the study that, among the different treatments T_5 (Funnel pheromone trap) was showed the best performance in capturing adult cucurbit fruit fly during the study period. At the 5 days after trap setting (DATS), the highest number of fruit fly (6.53) was captured in T_5 (Funnel pheromone trap) treatment, which was significantly different from the all others treatment, whereas the lowest number of fruit fly (3.07) was captured in T_6 (Sticky board trap) which was closely followed by 3.87 in T_4 (Bait trap with banana mashed) treatment. As a result, the trends of captured adult cucurbit fruit fly in different traps is T_5>T_1>T_3> T_2> T_4 >T_6 at 5 days after trap setting at the reproductive stage of bottle gourd. Similar trend of results were also found from the rest of different days after trap setting at the reproductive stage of bottle gourd, except untreated control treatment T_7.

The consequence of different traps against cucurbit fruits fly, *B. cucurbitae* on the basis of infested fruits by number of healthy fruits, the highest number of healthy fruits/plot (9.73, 11.67 and 10.27) were recorded from T_5 (Funnel pheromone trap) treatment, whereas the lowest number of healthy fruits/plot (6.67, 7.67 and 7.40) were recorded from T_7 (Untreated control) treatment at the early, mid and late reproductive stages of bottle gourd respectively during the study period. In case of the number of infested fruits, the highest number of infested fruits/plot (0.80, 0.87and 1.00) were collected from T_7 (Untreated control) on the other hand, the lowest number of infested fruits/plot (0.33, 0.27and 0.33) were collected from T_5 (Funnel pheromone trap) treatment at the early, mid and late reproductive stages of bottle gourd respectively during the study period.

In the same way, the lowest percent of fruit infestation (2.67, 2.22 and 3.13) by number were observed from T_5 (Funnel pheromone trap) treatment, On the other hand, the highest percent of infestation (10.65, 10.15 and 11.92) were observed from T_7 (Untreated control) treatment at the early, mid and late reproductive stages of bottle gourd respectively during the study period.

From the results also showed significant variations due to the effect of different traps on percent of infestation reduction over control of *B. cucurbitae* by number basis at the different reproductive stages of bottle gourd. Among different traps, T_5 (Funnel pheromone trap) showed more reduction (74.93%,78.13%) and 73.74%) of infestation due to cucurbit fruit fly and supported to make sure the more yield of bottle gourd at the early, mid and late reproductive stages of bottle gourd respectively during the study period.

In the similar trend, T_6 (Sticky board trap), showed lower performance to control cucurbit fruit fly while minimum reduction (30.05%, 13.60% and 19.71%) were recorded on bottle gourd at the early, mid and late reproductive stages of bottle gourd respectively. during the study period. As a result, the order of efficacy of different traps in terms of fruit infestation reduction at the early, mid and late reproductive stage is $T_5 > T_1 > T_3 > T_2 > T_4 > T_6 > T_7$.

The significance of different traps against cucurbit fruits fly, *B. cucurbitae* on the basis of infested fruits by weight of healthy fruits, the highest weight of healthy fruits/plot (24.60 kg, 34.60 kg and 33.20 kg) were recorded from T_5 (Funnel pheromone trap) treatment, whereas the lowest weight of healthy fruits/plot (17.60kg, 25.80kg and 21.20kg) were recorded from T_7 (Untreated control) treatment at the early, mid and late reproductive stages of bottle gourd respectively during the study period. In case of the weight of infested fruits, the highest weight of infested fruits/plot (2.12 kg, 5.00 kg and 3.60 kg) were collected from T_7 (Untreated control) on the other hand, the lowest weight of infested fruits/plot (1.13kg, 2.20kg and 1.80kg) were collected from T_5 (Funnel pheromone trap) treatment at the early, mid and late reproductive stages of bottle gourd respectively during the study period.

Similarly, the lowest percent of fruit infestation (4.40, 5.97 and 5.13) by weight were observed from T_5 (Funnel pheromone trap) treatment, On the other hand, the highest percent of infestation (10.53, 16.24 and 14.54) were observed from T_7 (Untreated control) treatment at the early, mid and late reproductive stages of bottle gourd respectively during the study period.

From the results showed significant variations due to the effect of different traps on percent of infestation reduction over control of *B. cucurbitae* by weight basis at the different reproductive stages of bottle gourd. Among different traps, T_5 (Funnel pheromone trap) showed more reduction (58.21%, 63.24%) and 64.72%) of infestation due to cucurbit fruit fly and supported to make sure the more yield of bottle gourd at the early, mid and late reproductive stages of bottle gourd respectively during the study period.

In the similar trend, T_6 (Sticky board trap), showed lower performance to control cucurbit fruit fly while minimum reduction (11.11%, 20.69% and 20.91%) were recorded on bottle gourd. As a result, the order of efficacy of different traps in terms of fruit infestation reduction by weight at early stage is T_5> T_1 and T_2> T_3> T4> T_6> T_7 and at the mid and late reproductive stage of bottle gourd is T_5> T_1 > T_3> T_2> T_4> T_6> T_7.

Significant variations were also observed on the impact of different traps in terms of length and girth of healthy fruits of bottle gourd. The highest length and girth of single fruit (55.91cm and 25.0 cm) were recorded in T_5 (Funnel Pheromone trap) which was statistically similar with 55.27cm and 24.55 cm in T_1 (Pheromone trap) treatments respectively. On the other hand the lowest length and girth of bottle gourd were 45.39 cm and 20.97cm in T_7 (Untreated control), which was statistically similar with 48.68 cm and 21.11 cm in T_6 (Sticky board trap) treatments respectively.

From the above finding it was observed that the highest bottle gourd length and girth was found in T_5 funnel pheromone trap.

Significant variations were observed among the treatments in terms of single fruit weight of healthy fruits. The highest single fruit weight was (2.95 kg) recorded in T_5 (Funnel

Pheromone trap) which was statistically similar with 2.85 kg in T_1 (Pheromone trap) treatment. On the other hand the lowest single fruit weight was 1.90kg recorded in T_7 (Untreated control) which was statistically similar with 1.95kg in T_6 (Sticky board trap) followed by 2.20 in T_4 (Bait trap with banana mashed) treatment.

In terms of fruit yield/ha, the highest healthy fruit yield and (69.96 t/ha) the lowest infested yield (19.45 t/ha) were achieved from T_5 (Funnel pheromone trap), whereas early, mid and late reproductive stages of bottle gourd respectively during the study period.

In the similar trend, T_6 (Sticky board trap), showed lower performance to control cucurbit fruit fly while minimum reduction (11.11%, 20.69% and 20.91%) were recorded on bottle gourd. As a result, the order of efficacy of different traps in terms of fruit infestation reduction by weight at early stage is $T_5 > T_1$ and $T_2 > T_3 >$ T4> $T_6 > T_7$ and at the mid and late reproductive stage of bottle gourd is $T_5 > T_1 > T_3 > T_2 > T_4 > T_6 > T_7$.

Significant variations were also observed on the impact of different traps in terms of length and girth of healthy fruits of bottle gourd. The highest length and girth of single fruit (55.91cm and 25.0 cm) were recorded in T_5 (Funnel Pheromone trap) which was statistically similar with 55.27cm and 24.55 cm in T_1 (Pheromone trap) treatments respectively. On the other hand the lowest length and girth of bottle gourd were 45.39 cm and 20.97cm in T_7 (Untreated control), which was statistically similar with 48.68 cm and 21.11 cm in T_6 (Sticky board trap) treatments respectively.

From the above finding it was observed that the highest bottle gourd length and girth was found in T_5 funnel pheromone trap.

Significant variations were observed among the treatments in terms of single fruit weight of healthy fruits. The highest single fruit weight was (2.95 kg) recorded in T_5 (Funnel Pheromone trap) which was statistically similar with 2.85 kg in T_1 (Pheromone trap) treatment. On the other hand the lowest single fruit weight was 1.90kg recorded in T_7 (Untreated control) which was statistically similar with 1.95kg in T_6 (Sticky board trap) followed by 2.20 in T_4 (Bait trap with banana mashed) treatment.

CONCLUSION

The cucurbit fruit fly, *Bactrocera cucurbitae* is one of the most serious insect pests of cucurbits vegetable. The fruit fly develops through egg, three instars, and pupa, pre-pupa and adult stages. The insect *B. cucurbitae* is more or less active throughout the study period but more active month of January. The present research work may be concluded that incidence of cucurbit fruit fly and infestation of bottle gourd by cucurbit fruit fly significantly varied among the treatments.

Considering the adult captured by different traps, percent of healthy and infested fruits both by weight and by number, percent infestation over control the treatment T_5 (Funnel Pheromone trap) showed the best performance for controlling of the *B. cucurbitae* among all the treatments. T_1 (Pheromone trap) showed the second highest performance in terms of healthy, infested and total fruit yield by controlling cucurbit fruit fly and treatment T_6 (Sticky board trap) showed the lowest performance .

Therefore, the use of different traps is becoming the most economical and practical approach in the integrated management of this pest. It offers many advantages such as (i) few additional cost for the farmers, (ii) no special skills to use, (iii) safe to the environment and (iv) compatibility with other measures of pest control.

RECOMMENDATION

- Considering the results of two experiments, it could be suggested that in most cases, the cucurbit fruit fly, *B. cucurbitae* could be minimized by use of different traps for encouraging the activities beneficial. Another reason to discourage the use of insecticides is their toxicity for causing hazard to the users, consumers and the environment also.
- Further study is recommended to assess the environment friendly management practices of important agricultural pests in various practices prevailing in different agro-ecosystem of Bangladesh.

CHAPTER VI

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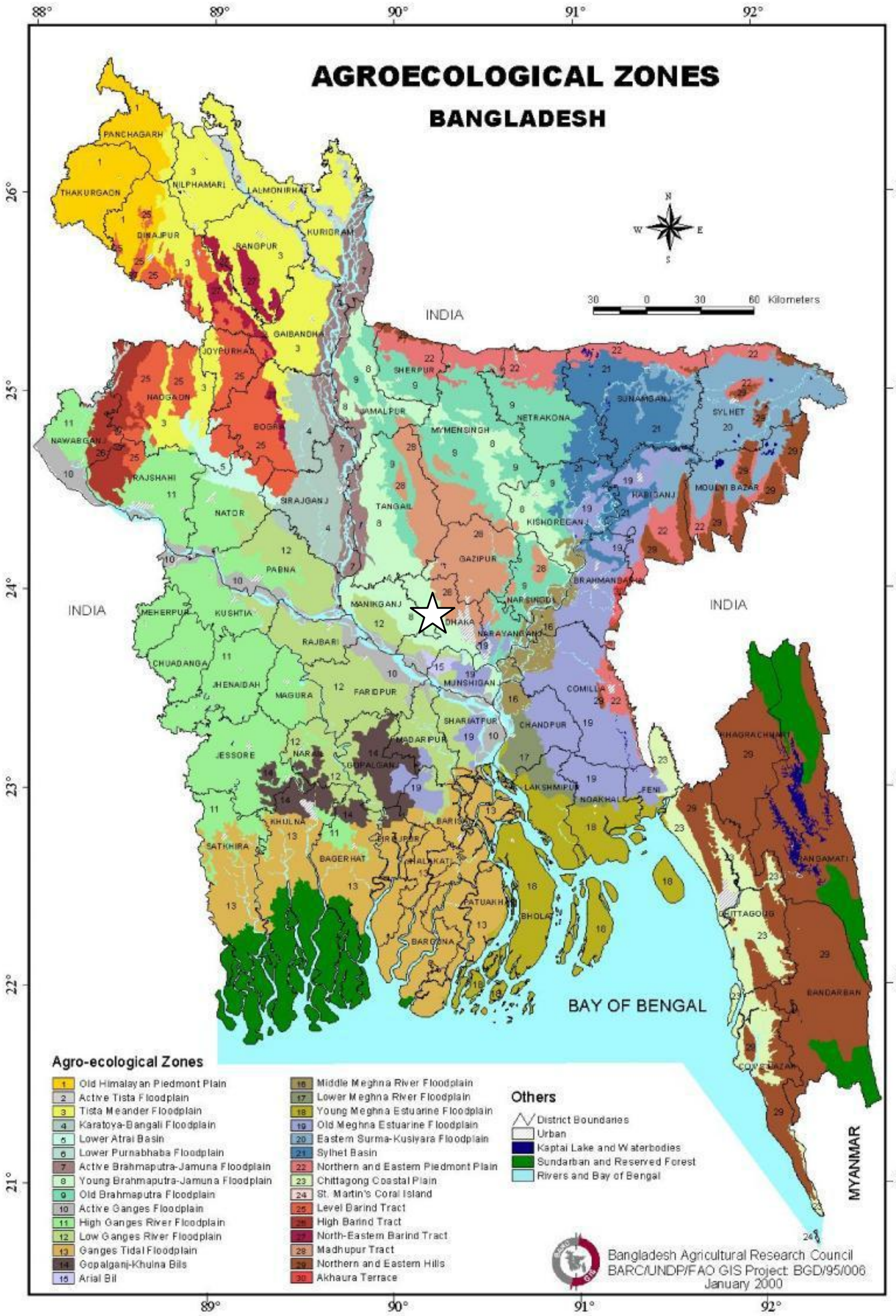
Appendix I. Experimental location on the map of Agro-ecological Zones of Bangladesh.



Source: Bangladesh Agricultural Research Council, Khamarbari, Dhaka.

Appendix II. Analysis of variance of the data on number of captured insects/trap at different days after trap setting at the reproductive stage of bottle gourd

Source of variation	Degrees of freedom	Mean square									
		Number of captured insects/trap at different days after setting of trap									
		3	6	9	12	15	18	21	24	27	30
Replication	2	0.024	0.008	0.025	0.006	0.003	0.022	0.006	0.004	0.007	0.001
Treatment	6	0.782**	0.562**	2.145**	0.571**	0.451**	0.782**	0.456**	0.0986**	0.1452**	0.134**
Error	12	0.082	0.064	0.112	0.048	0.027	0.091	0.030	0.0102	0.0172	0.006

**: Significant at 0.01 level of probability

Appendix III. Analysis of variance of the data on healthy, infested fruits and fruit infestation by number at early reproductive stage of bottle gourd due to the efficacy of different traps against cucurbit fruits fly

Source of variation	Degrees of freedom	Mean square		
		Number of fruits/plant		% infestation
		Healthy fruit (No.)	Infested fruit (No.)	
Replication	2	0.022	0.004	0.371
Treatment	6	0.782**	0.178**	12.452**
Error	12	0.069	0.0133	1.542

**: Significant at 0.01 level of probability

Appendix IV. Analysis of variance of the data on healthy, infested fruits and fruit infestation by number at mid reproductive stage of bottle gourd due to the efficacy of different traps against cucurbit fruits fly

Source of variation	Degrees of freedom	Mean square		
		Number of fruits/plant		% infestation
		Healthy fruit (No.)	Infested fruit (No.)	
Replication	2	0.001	0.002	0.310
Treatment	6	0.491**	0.145**	9.781**
Error	12	0.032	0.009	0.726

**: Significant at 0.01 level of probability

Appendix V. Analysis of variance of the data on healthy, infested fruits and fruit infestation by number at late reproductive stage of bottle gourd due to the efficacy of different traps against cucurbit fruits fly

Source of variation	Degrees of freedom	Mean square		
		Number of fruits/plant		% infestation
		Healthy fruit (No.)	Infested fruit (No.)	
Replication	2	0.004	0..001	0.281
Treatment	6	1.451**	0.287**	8.562**
Error	12	0.042	0.006	0.556

**: Significant at 0.01 level of probability

Appendix VI. Analysis of variance of the data on healthy, infested fruits and fruit infestation by number at early reproductive stage of bottle gourd due to the efficacy of different traps against cucurbit fruits fly

Source of variation	Degrees of freedom	Mean square		
		Weight of fruits/plant		% infestation
		Healthy fruit (kg)	Infested fruit (kg)	
Replication	2	0.267	0.001	0.089
Treatment	6	3.673*	0.189*	2.786*
Error	12	0.898	0.011	0.384

**: Significant at 0.01 level of probability; *: Significant at 0.05 level of probability

Appendix VII. Analysis of variance of the data on healthy, infested fruits and fruit infestation by number at mid reproductive stage of bottle gourd due to the efficacy of different traps against cucurbit fruits fly

Source of variation	Degrees of freedom	Mean square		
		Weight of fruits/plant		% infestation
		Healthy fruit (kg)	Infested fruit (kg)	
Replication	2	0.782	0.011	0.034
Treatment	6	6.562*	0.167*	3.564**
Error	12	2.926	0.049	0.129

**: Significant at 0.01 level of probability; *: Significant at 0.05 level of probability

Appendix VIII. Analysis of variance of the data on healthy, infested fruits and fruit infestation by number at late reproductive stage of bottle gourd due to the efficacy of different traps against cucurbit fruits fly

Source of variation	Degrees of freedom	Mean square		
		Weight of fruits/plant		% infestation
		Healthy fruit (kg)	Infested fruit (kg)	
Replication	2	0.562	0.013	0.128
Treatment	6	4.562*	1.673**	1.894*
Error	12	1.549	0.035	0.472

**: Significant at 0.01 level of probability; *: Significant at 0.05 level of probability

Appendix IX. Analysis of variance of the data on yield contributing characters of bottle gourd due to the effect of different traps against fruit fly and its impact

Source of variation	Degrees of freedom	Mean square		
		Length of single fruit (cm)	Girth of single fruit (cm)	Single fruit weight (kg)
Replication	2	1.278	0.451	0.005
Treatment	6	134.787**	6.894*	1.234**
Error	12	11.914	2.297	0.019

**: Significant at 0.01 level of probability; *: Significant at 0.05 level of probability

Appendix X. Analysis of variance of the data on yield/ha during total cropping season of bottle gourd due to the effect of different traps against fruit fly and its impact

Source of variation	Degrees of freedom	Mean square	
		Healthy fruit yield (t/ha)	Infested fruit yield (t/ha)
Replication	2	2.134	0.342
Treatment	6	56.675*	9.893**
Error	12	14.905	0.919

**: Significant at 0.01 level of probability; *: Significant at 0.05 level of probability