# ECOFRIENDLY MANAGEMENT OF CUCURBIT FRUIT FLY ON BITTER GOURD


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# ECOFRIENDLY MANAGEMENT OF CUCURBIT FRUIT FLY ON BITTER GOURD

**BY**

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## CERTIFICATE

This is to certify that thesis entitled **"ECOFRIENDLY MANAGEMENT OF CUCURBIT FRUIT FLY ON BITTER GOURD"** submitted to the **Faculty of Agriculture,** Sher-e-Bangla Agricultural University (SAU), Dhaka in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (MS) IN ENTOMOLOGY**, embodies the result of a piece of bona fide research work carried out by **TUBA MAHPARA, Registration no. 10-04008** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

**Dated: DECEMBER, 2015**
**Place: Dhaka, Bangladesh**

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# ECOFRIENDLY MANAGEMENT OF CUCURBIT FRUIT FLY ON BITTER GOURD

**TUBA MAHPARA**

## ABSTRACT

A field experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University to find out the effective as well as hazards free management practice(s) of cucurbit fruit fly infesting bitter gourd cultivated during Kharif I season (February 2016 to June 2016). The experimental treatments were $T_1$ comprised of setting up of pheromone trap replaced at 1 month interval, $T_2$ comprised of setting up of poison bait trap @ 2 gm Sevin 85 WP mixed with 100 g mashed sweet gourd and 10 ml molasses replaced at 4 days interval, $T_3$ comprised of spraying of Spinosad @ 0.08 ml per liter of water at 7 days interval, $T_4$ comprised of bait spray @ 10 ml molasses and 1 ml Malathion mixed with 1 liter of water @ 7 days interval, $T_5$ comprised of the combination of $T_1$ and $T_2$; $T_6$ comprised of the combination of $T_1$ and $T_3$; $T_7$ comprised of the combination of $T_1$ and $T_4$; $T_8$ comprised of spraying of Neem oil @ 3 ml neem oil and 10 ml Trix mixed with 1 liter of water @ 7 days interval, and $T_9$ comprised of untreated control. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Pheromone trap in combination with poison bait trap ($T_5$) contributed to produce the highest number of fruit at early (26.67 fruit/plot), mid (37.33 fruit/plot) and late (27.00 fruit/plot) fruiting stage; total weight of fruit (838100 gm/plot) and reduced the maximum fruit infestation over control at early (94.23%), mid (94.48%) and late (85.05%) fruiting stage. The highest yield (24.03 t/ha) was recorded in $T_5$ which contributed to increase the highest yield (163%) over control. The yield of bitter gourd was negatively correlated with the fruit infestation by number at early, mid and late fruiting stage (r = 0.795, r = 0.910 and r = 0.937, respectively). The fruit yield was strongly and positively correlated with the length (r = 0.972), girth (r = 0.938), single fruit weight (r = 0.931) and number of fruit per plant (r = 0.932), i.e., yield of bitter gourd increased with the increase of the length, girth, single fruit weight and number of fruit per plant. The poison bait trap was more effective than pheromone trap in terms of capturing adult fruit fly per trap throughout the cropping season, where in case of poison bait trap the average number of adult fruit flies captured per trap was 32.6 and in case of pheromone trap this number was 17.49 fruit flies per trap. The higher temperature ($35^oC$) negatively affected the capturing of adult fruit fly for poison bait trap because of drying up of bait materials, but not affected on the adult capturing capacity of pheromone trap. The highest benefit cost ratio (43.20) was also found for $T_5$ and the lowest BCR (14.91) for $T_8$. Considering the social acceptance and environmental safely point of view, $T_5$ comprising pheromone trap along with poison bait trap was the most effective management practices in reducing the fruit fly infestation. Thereby increasing the yield of bitter gourd.

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# CHAPTER I

# INTRODUCTION

Cucurbits are the major groups among vegetables grown in Bangladesh (Nasiruddin *et al*., 2004).Vegetables are cultivated in 885127 acre of land and annual production of vegetables is only 2726723 metric tons (MT). Among them, cucurbitaceous vegetables occupy about 66% of the lands under vegetables cultivation and contribute 15.25% of total vegetables production (BBS, 2013). In 2012-2013 cropping year, 52020 metric tons bitter gourd was produced in Bangladesh (BBS, 2013).

Bitter gourd (*Momordica charantia*) is a young, tender, edible fruit-pod of climbing vines. It belongs to the Cucurbitaceae family. It is one of popular edible vegetable in many Asian countries including Bangladesh. It is very low in calories, carrying just 17 calories per 100 g. The plant has medicinal properties and a compound known as 'Charantin' present in the bitter gourd is used to reduce blood sugar for diabetic patient (Dhillon *et al*., 2005a). Bitter gourd is also rich in Carbohydrates. It is also rich in Iron, Vitamin A, Vitamin B, and Vitamin C (Gopalan *et al.,* 1982). It can be cultivated any time of the year but it is cultivated mainly in the Kharif season. Bangladesh Agricultural Research Institute (BARI) has released high yielding bitter gourd variety "BARI Karala -1". Bangladesh Agricultural Development Corporation (BADC) has released bitter gourd variety "Gaj Karala". Besides these, Lal Teer seed company has released bitter gourd variety Tia, Parrot and Taj.

Fruit fly, *Bactrocera cucurbitae* Coquillet, is a major pest causing yield loss in bitter gourd grown in Bangladesh. Fruit flies reduce yield as well as the quality fruit (IPM CRSP, 2004). Yield losses due to fruit fly infestation vary from 19.19 to 69.96 percentages in different fruits and vegetables (Kabir *et al.* 1991). Small farmers suffer in particular, being the growers of the highly susceptible items and unable to afford enough protection measures. Losses without control have been estimated as 21% of fruits and 24% of cucurbits in Pakistan (Stonehouse *et al.*, 1998).

The most important feature of the infestation caused by the fruit fly is to lay eggs beneath the fruit rind of cucurbits by puncturing it and larvae cause damage the pulp of fruits. It is important to prevent or minimize pest problems before serious outbreaks occur, to detect pest problems early, and to select appropriate controls. Traditionally farmers combat this noxious pest using chemical insecticides. But most of the cases, it is not possible to control it due to the larvae live in the internal portion of fruits. Even though, farmers use toxic chemicals without considering economic injury level (EIL) of the pest. Thus, toxic chemicals kill natural enemies, regular occurrence of upset and resurgence, residues of pesticides on edible fruits of cucurbits. But the bio-pesticides are completely safe for environment, health and nature. Therefore, the judicious use of pesticides along with bio-pesticides is important in the management of pest resistance to pesticides, conservation of beneficial insects, minimizing the environmental hazards, improving the safety condition of workers in the field, and overall reducing the farm input costs. In view of the above analysis, the present research was conducted in consideration of eco-friendly management of cucurbit fruit fly by using different management practices along with bio-pesticides with the following objectives:

i. To assess the level of infestation of cucurbit fruit fly on bitter gourd;
ii. To evaluate the different management practices along with bio-pesticide for combating cucurbit fruit fly infesting bitter gourd;
iii. To find out the eco-friendly management practices of cucurbit fruit fly in comparison with traditional practices.

iv. Economic analysis of the management practices.

# CHAPTER II

# REVIEW OF LITERATURE

Cucurbit fruit fly, *Bactrocera cucurbitae* (Coquillett), is one of the most important pests of cucurbits, and bitter gourd (*Momordica charantia*) is highly prone to damage by this pest in Bangladesh. Because of the difficulties associated with the control of this pest by chemical insecticides, farmers experienced great losses in cucurbits. Therefore, the judicious use of pesticides along with bio-pesticides is important. The literatures on the ecofriendly management utilizing several non-hazardous components to combat this pest are very sporadic. For the purpose of this study, the most relevant information's are given below under the following sub-headings:

## 2.1Systemic 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*

## 2.2Synonyms

*Bactrocera cucurbitae* (Coquillett) has also been known as:

i) *Chaetodacus cucurbitae*
ii) *Dacus cucurbitae*
iii) *Strumeta cucurbitae*
iv) *Zeugodacus cucurbitae*

**Plate 1. Female cucurbit fruit fly** **Plate 2. Male cucurbit fruit fly**

**2.3 Origin and distribution of fruit fly**

Fruit fly 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; 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). Kapoor (1993) reviewed that fruit fly was originally reported from Hawaii and now widely distributed throughout the oriental region including China, Japan, much of the pacific including New Guinea, Soloman and Bismark Islands, Australia, Mauritius, East Africa, Kenya and Tanzania.

Fruit flies are distributed almost everywhere in the world and infest a large number of host plants. 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 (Kapoor, 1993). Two of the world's most damaging tephritids, *B. dorsalis* and *B. cucurbitae* are widely distributed in Malaysia and other South East Asian countries (Vijaysegaran, 1987). Gupta and Verma (1992) has cited references of five species of fruit fly in Bangladesh, e.g., *B. brevistylus* (melon fruit fly), *Dacus (Zeugodacus) caudatus* (fruit fly), *D. (Strumeta) cucurbitae* (melon fly), *D. (Bactrocera) dorsalis* Hendel (mango fruit fly) and *D. (Chactlodacus) zonatus* (zonata fruit fly). According to Akhtaruzzaman (1999) *B. cucurbitae, B. tau* and *D. ciliatus* have been currently identified in Bangladesh of which *D. ciliatus* is a new record. *B. cucurbitae* is dominant in all the locations of Bangladesh followed by *B. tau*and *D. ciliatus.*

**2.4 Biology and life cycle**

The melon fruit fly remains active throughout the year on one or the other host. During the severe winter months, they hide and huddle together under dried leaves of bushes and trees. During the hot and dry season, the flies take shelter under humid and shady places and feed on honeydew of aphids infesting the fruit trees. Fruit flies breed in fruits but also in other living plant tissues as leaves, buds, stems and flowers. The host ranges of fruit flies can vary from monophagous (e.g. Mediterranean fruit flies) to highly polyphagous (e.g. Melon flies and Oriental fruit flies). Simplified it can be said that fruit flies go through four development stages; eggs, larvae (three larval instars), pupae and adults. The life cycle from egg to adult takes between 14 and 27 days. The duration of each stage and degree of survival depends on species, host plant and environmental conditions (Shaw *et al*., 1967). Adult fruit flies have a diet based on secretion of plants from leaves, fruits and rotting fruits but also nectar, pollen, bird feces, and honeydew secreted by other insects (Christenson and Foote, 1960). Protein obtained from for example honeydew helps fruit flies to reach a normal fertility and stimulates egg production. Studies on fruit fly mating behaviour revealed that most of flies in tropical and subtropical areas mate when light intensity decreases at dusk (Bateman, 1979). Although some species belonging the genus *Bactrocera* prefer to mate in the morning and early afternoon (Alwood and LeBlanc, 1997). Oviposition occurs in stings made by other fruit flies or other injures in the skin. Fruit flies can move long distances within a short time (Bateman, 1979). Exceptional observations made by Miyahara and Kawai (1979) showed than a species of the genus *Bactrocera* could move up to 200 km. During the larvae stage fruit flies can move long distances by jumping, these movements seem to be in random directions (Christenson and Foote, 1960) and are probably defence behaviour against insect predators (Fletcher, 1987). Mating between the adult male and female cucurbit fruit flies generally takes place at about dusk and lasts for about an hour or more (Narayanan and Batra, 1960). The eggs laid by *Bactrocera cucurbitae* are creamy white, oblong, banana shaped and are about 1.3 mm in length (Anon, 1987). The incubation period of eggs is 2-3 days during March and April and 24-36 hours throughout the summer months. It may be prolonged up to ten days in winter. Larval period is 4-7 days varying with temperature. The pupa is cylindrical in shape and is 4-5 mm long and 2 mm broad. The color varies from dull deep reddish yellow to pale white. The pupal stage lasts for 8-12 days at 23-25°C and 9 days at 27°C. Adults begin to mate 9-12 days after emergence (Rituraj, 2011).

The adult fly *(B. cucurbitae}* is about 8 mm in body length; reddish brown in color with yellow stripes on its dorsal thorax and has brown spots along the veins otherwise clear wings. In late hours of the day, the female flies lay eggs on the tender fruits. The eggs lay by *B. cucurbitae* inside the fruit, which are creamy, white in color; oblong; banana shaped and is about 1.3 mm in length (Anon, 1987). Eggs are normally inserted under the skin of the fruits, vegetables, nuts or fleshy parts of plants, stems or flowers where they are protected from sun (Feron *et al*., 1958).The maggots feed inside just after hatching from the eggs. The creamy white maggot gradually becomes darker as it matures. The length of mature larvae is about 12 mm. The full grown larvae come out of the bores and make a loop holding the last abdominal segment by mouth hook and drop forcedly on the soil by releasing their mouth hook for pupation. This phenomenon takes place usually in the early morning between 6:00 am to 9:00 am. The most of the full grown larvae penetrate the soil rapidly and pupate under the soil surface. The larval period is 4-7 days, varying with temperature, nutritional condition, larval rearing density etc. (Anon, 1987). Pupation formation may require as little as one hour and complete within the puparium by less than 48 hours (Christenson and Foote, 1960). The larvae spend $4^{th}$ instar in the puparium formed by the exuviae of the $3^{rd}$ instar and subsequently become pupae. The puparium is 4.8 to 6.0 mm in length. At the 23-25$^{o}$C, the pupal stage lasts for 8-12 days. At 27°C, the mean pupal period for *B.dorsalis* and *Ceratitis capitata* (Wiedcmann) is 10 days and that for *B. cucurbitae* is 9 days (Mitchell *et al*., 1965).

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

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

**2.5 Seasonal abundance of fruit fly**

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 (Sujit, 2005). 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. 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.

Narayanan and Batra (1960) reported that most of the fruit fly species are more or less active at temperatures ranging between 12-15°C 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 adults of melon fly, *Bactrocera cucurbitae* over

winter from November to December and the fly is the most active during July to August (Agarwal *et al.,* 1987). The peak population of fruit fly in India is attained during rainy months of July and August and in cold months of January and February (Nair, 1986).

The fruit fly population is generally low during dry weather and increases rapidly with adequate rainfall (Butani and Jotwani, 1984). Amin (1995) also observed the highest population incidence at the ripening stage of cucumber in Bangladesh. Nasiruddin (1991) observed that the incidence of fruit flies was the highest in February and the lowest in September.

Yao and Lee (1978) observed that populations of oriental fruit fly were higher in the ripening season of any fruit in Taiwan. Kapoor (1993) reviewed that the fruit fly *B. cucurbitae* Coquillett and *B. zonata* Saunders are active throughout the year except for a short period from December to mid February due to excessive cold when they hide under the leaves of guava, citrus fruits and mangoes etc. The peak population of fruit fly in India is attained during July and August in rainy season and January and February in cold months (Nair and Thomas, 1999).

**2.6 Host range**

Many fruit fly species do serious damage to vegetables, oil-seeds, fruits and ornamental plants. 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. Based on the extensive surveys carried out in Asia and Hawaii, plants belonging to the family Cucurbitaceae are preferred most (Allwood *et al.*, 1999). 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. Lawrence (1950) recorded that cucurbit vegetables are the most favorite 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 attacking through the female flower. Kapoor (1993) reported that more than one hundred vegetables and fruits are attacked by *Bactrocera sp.* Atwal (1993) and McKinlay *et al.* (1992) reported that cucurbits as well as 70-100 non-cucurbitaceous vegetables and fruits are the host of fruit fly. In Bangladesh, Alam (1962) recorded ten cucurbit vegetables as the host of fruit fly. Tomato, green pepper, papaya, cauliflower, mango, guava, citrus, pear, fig and peaches are also infested by fruit fly (Atwal, 1993andAnon., 1987). Sixteen species of plants act as the host of fruit flies among which sweet gourd was the most preferred host for 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 (Kabir *et al*., 1991). The males pollinate the flowers and acquire the floral essence and store it in the pheromone glands to attract non-specific females (Hong and Nishida, 2000).

Doharey (1983) reported that it infests over 70 host plants, among which fruit of bitter gourd (*Momordica charantia*), musk melon (*Cucumis melo*), snap melon (*Cucumis melo* var. *momordica*) and snake gourd (*Trichosanthes anguina* and *T. cucumeria*) are the most preferred hosts. According to Narayanan and Batra (1960) different species of fruit fly attack a wide variety of fruit and vegetables such as mango, guava, plum, peach, pear, fig, apple, quince, persimmon, banana, pomegranate, jujube, sweet lime, orange, chilies, jack fruit, carambola, papaya, avocado, bread fruit, coffee, berries, passion fruit, star apple, Spanish pepper, cucurbits etc. White and Elson-Harris (1994) stated that many of the host records might be based on casual observations of adults resting on plants or caught in traps set in non-host plant species. In the Hawaiian Islands, melon fruit fly has been observed feeding on the flowers of the sunflower, Chinese bananas and the juice exuding from sweet corn. Under induced oviposition, McBride and Tanda (1949) reported that broccoli (*Brassica oleracea* var. *capitata*), dry onion (*Allium cepa*), blue field banana (*Musa paradisiaca* sp. *sapientum*), tangerine (*Citrus reticulata*) and longan (*Euphoria longan*) are doubtful hosts of *B. cucurbitae*. Themelon fly has a mutually beneficial association with the orchid, *Bulbophyllum paten, which* produces zingerone. According to Mathew *et al.* (1999), *B. cucurbitae* infesting vines of cucumber and bitter gourd and the first report in cowpea pods. *Brassica caulorapa* (*Brassica oleracca* var. *gongylodes)* was confirmed as a food plant of *B. cucurbitae* (Ranganath *et al.,* 1999). *B. cucurbitae* was recently recorded infesting tomato in South Andaman, Andaman and Nicobar Islands, India (Ranganath and Veenakumari, 1996). Based on the extensive surveys carried out in Asia and Hawaii, plants belonging to the family Cucurbitaceae are preferred host (Allwood *et al*, 1999).

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).

Thirteen cucurbit crops were screened for their resistance to the fruit fly (*B.cucurbitae*) during the summer and rainy seasons of 2001 and 2002, in Varanasi, Uttar Pradesh, India. None of the cucurbits were found free from pest attack during both seasons. However, significant differences were observed in the degree of infestation among cucurbits. Damage during the summer season of 2001 and 2002 was maximum in bitter gourd (26.11 and 31.96%) and minimum in pumpkin (2.78 and 1.39%). Similarly, damage during the rainy season of 2001 and 2002 was maximum in bitter gourd (46.8 and 45.3%) and minimum in pumpkin (7.4 and 11.1%). Bitter gourd, followed by bottle gourd, was the most preferred host of *B. cucurbitae* (Nath and Bhushan, 2006).

## 2.7 Nature of damage of fruit fly

According to Janjua (1948), the nature of infestation of fruit fly varies with the kinds of fruits. Shah *et al.* (1948) and York (1992) observed the formation of brown resinous deposits on fruits as the symptom of infestation.

Fruit flies damage fruits by puncturing and laying eggs under the soft skin in both mature and green fruits (Hollingsworth and Allwood, 2000). The eggs hatch and feed inside the fruit causing the fruits to rot (Dhillon, 2005b) resulting in unmarketable fruits. Due to the larva's three instars the fruits can be totally destroyed (Ye and Liu, 2005). Furthermore, injuries caused by the larvae may be used as gateways by secondary organisms (e.g. bacteria and fungi) and contribute to further destruction of the fruit. At maturity, larvae emerge from the damaged fruit and drop to the ground and pupate in a burrow (4-8 cm) prepared by the prepupa. Infested fruits often drop to the ground prematurely. Piercing by the ovipositor causes wounds on the fruit or vegetables in the form of punctures, which appear like dark spots on the surface. In freshly punctured specimens, the fluid that exudes accumulates in the form of a droplet which later dries up and appears like brown resinous deposit (York, 1992; Narayanan and Batra, 1960; Shah *et al.*, 1948). Inside the damage fruits small white color larvae are present (Praveen *et al*., 2012). After hatching the larvae feed into pulp tissue and make tunnels in fruits causing direct damage. They also indirectly damage the fruits by contaminating with grass and accelerate rotting of fruit by pathogenic infection. In infested fruits if not rotten become deformed and hardy which make it unfit for human consumption. The infested flower often becomes juicier and drops from the stalk at a slight jerk (Kabir *et al*., 1991).

According to Kapoor (1993), some flies make mines and a few form galls on different parts of the plants. Singh (1985) reviewed that the maggots bore and feed inside the fruits causing sunken discolored patches, distortion and open cracks.

In Hawaii, pumpkin and squash are heavily damaged even before fruit set. The eggs are laid into unopened flowers, and the larvae successfully develop in the taproots, stems, and leaf stalks (Weems and Heppner, 2001). The vinegar fly, *Drosophilla* *melanogaster* has also been observed to lay eggs on the fruits infested by melon fly, and acts as a scavenger (Dhillon *et al.*, 2005c).

**Plate 3.Healthy bitter gourd**

**Plate 4. Fruit fly infested bitter gourd**

**Plate 5. Fruit fly infested bitter gourd**

**Plate 6. Larvae inside the bitter gourd** **Plate 7. Larvae under microscope**

**2.8 Rate of infestation and yield loss by fruit fly**

Depending on the environmental conditions and susceptibility of the crop species, the extent of losses varies between 30 to 100% (Shooker et al., 2006; Dhillon *etal*., 2005d; Gupta and Verma, 1992). According to the reports of Bangladesh Agricultural

Research Institute, fruit infestations were 22.48, 41.88 and 67.01% for snake gourd, bitter gourd, and musk melon, respectively (Anon, 1988). Kabir *et al*. (1991) reported that yield losses due to fruit infestation varies in different fruits and vegetables and it is minimum in cucumber (19.19%) and maximum in sweet gourd (69.96%). In cucumber, Amin (1995) observed 42.08 % fruit infestation while, Uddin (1996) reported 45.14% infestation. The infested fruits become rotten, dry up and finally shed up prematurely (Gupta and Verma, 1992). Fruit infestation by melon fruit fly in bitter gourd has been reported to vary from 41 to 89% (Rabindranath and Pillai, 1986; Gupta and Verma, 1978).

Borah and Dutta (1997) studied the infestation of Tephritids on the cucurbits in Assam, India and obtained the highest fruit fly infestation rate in snake gourd (62.02%). Larger proportion of marketable fruits was obtained from ash gourd in Kharif and bottle gourd in summer season. Snake gourd and pumpkin yielded the lowest proportion of marketable fruits. Gupta (1992) investigated the rate of infestation of *D. cucurbitae (B. cucurbitae)* and *D. tau* on cucurbits in India during 1986-87 and recorded that 80% infestation on cucumber and bottle gourd in July-August and 60% 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. Among these vegetables the intensity of fruit fly infestation was numerically the highest in sweet gourd (32.5-± 3.9) and the lowest in sponge gourd (14.7 ± 4.0).

Experiment revealed that fruit flies attack melon and teasel gourd within 1 to 11 and 3 to 11 days after fruit setting when the average fruit size ranged from 1.38 x 0.78 cm to 3.53 x 2.07 cm and *2*.13x 1.18cmto 4.98 x 3.1 cm, respectively (Anon., 1988). Maximum infestation (26.67%) in melon occurred in the 4$^{th}$ day after fruit setting when average fruit size was 2.03 x 1.08 cm. In teasel gourd, it was 19.28% on 8th day after fruit setting when average fruit size was 4.57 x 2.91 cm (Anon., 1988). Amin (1995) and Uddin (1996) observed 42.08 and 45.14% fruit fly infestation in cucumber, respectively.

The field experiment on assessment of yield losses caused by cucurbit fruit fly in different cucurbits have been reported as 28.7-59.2, 24.7-40.0, 27.3-49.3, 19.4-22.1 and 0-26.2% in pumpkin, bitter gourd, bottle gourd, cucumber and sponge gourd respectively, in Nepal (Pradhan, 1976). The melon fruit fly has been reported to infest 95% of bitter gourd fruit in Papua New Guinea, and 90% snake gourd and 60 to 87% pumpkin fruit in Solomon Island (Hollingsworth *et al*., 1997). Singh *et al.* (2000) reported 31.27% damage on bitter gourd and 28.55% on water melon in India. York (1992) reviewed that the loss of cucurbits caused by fruit fly in South East Asia might be up to 50%.The damage caused by fruit fly is the most serious in melon after the first shower in monsoon when the infestation often reaches up to 100%. Other cucurbit might also be infested and the infestation might be gone up to 50% (Atwal, 1993). Shah *et al.* (1948c) reported that the damage done by fruit flies in North West Frontier Province (Pakistan) cost an annual loss of over $ 655738.

## 2.9 Fruit fly behavior

Melon flies are most often found on low, leafy, succulent vegetation near cultivated areas. In hot weather they rest on the undersides of leaves and in shady areas. They are strong fliers and usually fly in the mornings and afternoons. They feed on the juices of decaying fruit, nectar, bird feces, and plant sap (Agarwal *et al*., 1987). Narayanan and Batra (1960) observed that as soon as the ovipositor is drawn out of the fruit for oviposition the fruit fly walks a short distance and pauses for a while to clean the fully extended ovipositor by movement of the hind pair of legs.

### 2.10 Management of fruit fly

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

#### 2.10.1 Management with pheromone trap

Pheromones are a class of semio-chemicals that insects and other animals release to communicate with other individuals of the same species. The key to these entire behavioral chemical is that they leave from the body of the first organism, pass through the air (or water) and reach the second organism, where they are detected by the receiver. In insects, these pheromones are detected by the antennae. Since pheromone is naturally occurring biological products, they are environmentally safe, non target organisms are not affected, insect are less likely to develop resistance and moreover they are effective at incredibly low concentrations. Sex pheromones have been utilized in the insect pest control program through population monitoring, survey, mass-trapping, mating disruption and killing the target pest in the trap (Bottrell, 1979).

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

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

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

diazinon; Cue-lure® 95% + naled) are available on the market, and have been found to be effective in controlling this pest (Iwaizumi *et al*., 1991). Chowdhury *et al*. (1993) captured 2.36 to 4.57 flies/ trap/ day in poison bait traps containing trichlorfon in bitter gourd. The use of male lure cearlure B1® (Ethylcis-5-Iodo-trans-2-methylcyclohexane-1-carboxylate) have been found to be 4-9 times more potent than trimedlure® for attracting medfly, *Ceratitis capitata* males (Mau *et al*., 2003), and thus could be tried for male annihilation strategies of melon fruit fly area wide control programs. Jaiswal *et al.* (1997) reported that in Nepal integrated control with pheromone traps, field sanitation and bagging of individual fruits proved very effective against *Bactrocera cucurbitae*.

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

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

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

YubakDhoj (2001) reported that Fruit fly (*Bactrocera cucurbitae* Coquilet. Diptera: Tephritidae) is considered one of the production constraints in Nepal. Elsewhere integrated pest management of fruit flies (*B. cucurbitae*) is achieved by using combined control methods such as male annihilation, using cue lure and malathion in Steiners traps by disrupting mating with appropriate field sanitation, bagging of individual fruits, using pesticides in soils and with bait spraying along with hydrolysed protein.

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

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

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

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

Hossen (2012) reported that the highest performance was achieved from Pheromone trap with funnel + Bait trap where Pheromone trap with funnel showed the second highest performance in terms of healthy, infested and total fruit yield by controlling cucurbit fruit fly and control treatment showed the lowest performance along with the treatment of T1 (Only pheromone trap).

**2.10.2 Management with poison bait trap**

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

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

Samalo *et al.* (1995) reported that baiting with dichlorvos, monocrotophos or quinalphos at a concentration of 0.025% killed 100% of adults within 6 h, as compared with 6.6% mortality in a 10% sugar solution. Contact toxicity tests showed that chlorpyrifos, endosulfan and dichlorvos caused 100% mortality of adults in 18 h as compared with 3.3% mortality of untreated adults. Chowdhury *et al.* (1993) captured 115.16 to 167.48 flies/ trap/ season in poison bait traps containing trichlorfon in bitter gourd.

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

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

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

**2.10.3 Management with spinosad**

Spinosad is a natural compound with insecticidal activity that has many properties considered to be highly desirable for insect control programs (Sparks *et al.*, 2001). This compound has been shown to be highly effective on a wide range of pest species, yet at the same time appear to have limited impact on non target organisms, including mammals, that may be exposed to it. Moreover, spinosad is readily degradable by exposure to sunlight, thus minimizing any environmental burden that may occur as a result of widespread use. Spinosad acts as a stomach poison, although spinosad it is activated by both contact and ingestion (BCPC, 2006). Spinosad was originally collected from a Caribbean island in 1985 (Sparks *et al.*, 2001), and the formulation that is currently the most widely used as an insecticide consists primarily of the A and D forms of this compound, both of which are naturally produced by the bacterial species *Saccharopolyspora spinosa*. Insecticide compounds based on spinosad have been extensively used as agents for control of insect pest species in the Diptera, Lepidoptera, Coleoptera, and Hymenoptera orders (M. B. Hertlein *et al*., 2010). among others. Within the Diptera, spinosad has been shown to be effective for control of Tephritid species within the Ceratitis, Bactrocera, Rhagoletis, and Dacus genera

(Sparks *et. al.*, 2001). As with any compound used for control programs, however, one concern over such widespread use is the potential for resistance to this compound to arise either in laboratory and/or natural populations. Indeed, the history of both natural and artificial compounds used for insect control is replete with examples of resistance development even where much more highly toxic compounds such as DDT or malathion have been used (C. Magana *et al.*, 2007; G. P. Georghiou, 1986). For most of the past forty years, organophosphate-(OP) compounds were the sole insecticides used to suppress this pest. Recently, due to growing environmental concerns raised over the use of OPs, alternatives such as spinosad have also been used (R. I. Vargas, 2008; J. D. Barry *et al.*, 2006). As part of a formulation known as GF-120 (Dow AgroSciences, Indianapolis, IN, USA), spinosad has been employed as part of an area-wide fruit fly pest management program (HAW-FLYPM) to control melon flies in Hawaii since 2002 (R. F. L. Mau, 2006; R. F. L. Mau, 2007), and in central Taiwan since 2007.

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

**2.10.4 Management with bait spray**

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

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

Kiran Rana and Kanwar (2014) reported that combined treatment of cue-lure baited traps and poison bait spray was most effective in management of fruit flies with significantly less fruit damage as compared to control rather than their separate applications. Chaudhary and Patel (2008) reported higher yield in pumpkin with combined use of male annihilation technique and poison bait spray. Raghuvanshi *et al.,* (2008) and Chaudhary and Patel (2008), Vargas *et al.,* (2005) also reported similar results that poison bait spray and male annihilation techniques in combination proved to be efficient in suppression of fruit flies in Hawaii. However, deployment of indigenous bait traps along with cuelure traps may further reduce melon fly damage and increase yield as observed by Nasiruddin *et al*., (2002). Kiran Rana and H. S. Kanwar (2014) reported that evaluation of eco-friendly techniques for management of melon fruit flies (*Bactrocera* spp.) in bitter gourd (*Momordica charantia* L.).

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

Nasiruddin and Karim (1992) reported that bait spray (1.0 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. 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).

**2.10.5 Management with neem oil**

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

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

# CHAPTER III

# MATERIALS AND METHODS

The present study was conducted to evaluate the ecofriendly management of cucubit fruit fly on bitter gourd at the experimental field of Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh during February, 2016 to June, 2016.

**3.1 Location of the study**: The experiments were conducted in the experimental field under the Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka.

**3.2 Characteristics of soil**: The soil of the experimental area was silty loam belonging to the Non-Calcareous Dark grey Floodplain soils under the Agro Ecological Zone 12. The selected site was a well drained medium high land.

**3.3 Season of the study**: The study was conducted during Kharif I season (February 2016-June 2016).

**3.4 Materials used**: The bitter gourd BARI Korola-1 was cultivated in the field during Kharif-I for combating cucurbit fruit fly using different management practices.

**3.5 Design of experiment**: The experiment was laid out in Randomized Completely Block Design (RCBD) with three replications. Total 27 plots were made for conducting the experiments. The whole experimental plot was 20 m long and 15 m broad, which was divided into 3 equal blocks. Each of the 3 equal blocks has 9 plots assigned for 9 treatments. The size of a unit plot was 2.5 m long and 1.5 m broad. Distance of 0.75 m between blocks and 0.5 m between the plots was kept to facilitate different intercultural operations.

**3.6 Replication**: Each treatment of the experiment was replicated with three times in the field of bitter gourd.

**3.7 Treatment:** The cucurbit fruit fly will be controlled using following management practices:

| **Treatment** | Item | **Dose/Rate** |
|---|---|---|
| **$T_1$** | Pheromone trap | 1 pheromone trap per plot replaced at 1 month interval |
| **$T_2$** | Poison bait trap | 2 g Sevin 85 WP mixed with 100 g mashed sweet gourd and 10 ml molasses replaced at 4 days interval |
| **$T_3$** | Spinosad | 0.08 ml per liter of water @ 7 days interval |
| **$T_4$** | Bait spray | 10 ml molasses and 1 ml Malathion mixed with 1 liter of water @ 7 days interval |
| **$T_5$** | $T_{1+}$ $T_2$ | 1 trap per plot replaced at 1 month interval along with 2 g Sevin 85 WP mixed with 100 g mashed sweet gourd and 10 ml molasses replaced at 4 days interval |
| **$T_6$** | $T_{1+}$ $T_3$ | 1 trap per plot replaced at 1 month interval along with 0.08 ml per liter of water @ 7 days interval |
| **$T_7$** | $T_{1+}$ $T_4$ | 1 trap per plot replaced at 1 month interval along with 10 ml molasses and 1 ml Malathion mixed with 1 liter of water @ 7 days interval |
| **$T_8$** | Neem oil | 3 ml neem oil and 10 ml trix mixed with 1 liter of water@ 7 days interval |
| **$T_9$** | Untreated control | No treatment was used |

**3.8 Land preparation:** The land was ploughed with a power tiller and kept open to sunlight. The land was then cross-ploughed several times with a power tiller to obtain good tilth. All ploughing operations were followed by laddering for breaking up the clods and leveling the surface of soil. The weeds and stubbles were removed from the field during land preparation. Finally, the unit plots were prepared as 10 cm raised beds along with basal doses of Urea 1 kg, TSP 1 kg, MoP 1 kg, Cowdung 5 kg, Potash, other micronutrients were applied as recommended by Rashid, 2006, during land preparation. The experimental field was divided into three blocks maintaining 1m block to block distance and each block were subdivided into 9 plots for treatment and the field was divided into 27 plots. There was 6 pits per plot. Pit to pit distance was 1.25 m.

**Plate 8. Whole experimental plot**

**3.9 Collection of seed and seedling raising:** The seeds of bitter gourd (BARI Korola-1) was collected from Horticulture Research Centre (HRC) of Bangladesh Agricultural Research Institute, Joydebpur, Gazipur. The seeds were sown in the organic matter containing polybags.

**Plate 9. Seedling raising in polybag**

**3.10 Transplanting of seedling:** The one month old seedlings grown in the polybags were transplanted in the sub plots of the main field.

**Plate 10. Seedling transplanting**

**3.11 Intercultural operation:** The watering and other intercultural operations were done for each of the seedlings transplanted in the field and a bamboo stick was used for each of the seedlings for supporting the seedlings.

**3.12 Treatment application**: Various treatments as mentioned earlier were applied to the respective sub-plot of the bitter gourd in the main field. The first application of the treatment was started just one week after the transplanting of the seedlings in the main field and continued up to one week before the harvest of the fruits.

**3.13 Management with trap**

**3.13.1 Management with pheromone trap**

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 4 days each. At each four days interval the number of insects trapped was recorded. In case of trapping, number of trapped fruit flies was counted. Total fruit and infested fruits were recorded and percentage of infested fruit was calculated.

**Plate 11. Pheromone trap hanging in the field**

**Plate 12. Trapped fruit flies in Pheromone trap**

**3.13.2 Management with poison bait trap**

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

**Plate 13. Poison bait trap set up in the field**

**Plate 14. Trapped fruit flies in poison bait trap**

### 3.13.3 Management with Spinosad

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

### 3.13.4 Management with bait spray

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

### 3.13.5 Management with botanical insecticide

**Spraying of neem oil**

Neem oil (*Azadirachta indica*) was used as botanical insecticide in fruit fly management experiment. Neem oil was collected from the local market Siddique Bazar, Dhaka. The required spray volume was prepared by mixing 75 ml neem oil (3%), 1 ml Trix (liquid detergent as mixing agent) with 2.5 litres of water. The detergent was used to break the surface tension of water and to help the solubility of neem oil in water. This preparation might have repelling and antifeeding actions against fruit fly. The mixture was sprayed at each 7 days interval in the selected plots.

### 3.13.6 Untreated control

The randomly selected 3 plots were kept untreated, where no treatment was applied.

**3.14 Data collection:** The collection of data was started at flower initiation of the cucurbit and collected from the fields at 7 days interval on following parameters:

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

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

**3.15 Calculation of data:** Percent of fruit infestation by number and weight will be calculated using the following formula:

$$\% \text{ Fruit infestation} = \frac{\text{Number of the infested fruit}}{\text{Total number of fruit}} \times 100$$

% Reduction over control = $\frac{X_2 - X_1}{X_2} \times 100$

Where, $X_1$ = the mean value of the treated plot

$X_2$ = the mean value of the untreated plot

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

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

**3.16.2 Gross Return (GR):** The yield in terms of money that was measured by multiplying the total yield by the unit price of bitter gourd (Tk 30/kg).

**3.16.3 Net Return (NR)** = The Net Return was calculated by subtracting treatment wise management cost from gross return.

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

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

**3.17 Data analysis**: All the collected data was analyzed following the analysis of variance (ANOVA) technique with the help of MSTAT-C Computer Package and the mean differences was adjusted by Duncan’s Multiple Range Test (DMRT) technique.

# CHAPTER IV

# RESULTS AND DISCUSSION

This chapter comprises the presentation and explanation of the results obtained from the experiment on the incidence of cucurbit fruit fly in bitter gourd and their management. The data have been presented and discussed and possible interpretations are made under the following sub-headings:

## 4.1 Fruit infestation by number at early fruiting stage

The effect of management practices on fruit infestation by number at early fruiting stage has been shown in Table 1. Significant variations were observed among the treatments in terms of fruit fly infestation on bitter gourd. The highest number of fruit per plot (26.67) was recorded in $T_5$, which was statistically similar with $T_7$ (25.67 fruits/plot), followed by $T_1$ (22.33 fruits/plot), $T_2$ (22.00 fruits/plot) and $T_4$ (21.00 fruits/plot). On the other hand, the lowest number of fruit per plot (12.00) was recorded in $T_9$, which was statistically different from all other treatments. Accordingly, the lowest number of infested fruit per plot (1.66) was recorded in $T_5$, which is statistically similar with $T_2$ (2.66), $T_1$ (2.66) and $T_7$ (2.00).

Considering the level of infestation, the lowest fruit infestation (6.28%) by number was recorded in $T_5$, which was statistically similar with $T_7$ (7.81%), followed by $T_1$(11.92%), $T_2$ (12.14%) and $T_4$(15.98%). On the other hand, the highest fruit infestation by number was recorded in $T_9$ (97.65%).

Considering the reduction of fruit infestation, the highest reduction of fruit infestation over control was observed 93% in $T_5$, followed by $T_7$ (92%), $T_1$ (88%) and $T_2$ (88%).Whereas the lowest reduction of fruit infestation over control was observed in $T_3$ (63%) and $T_8$ (63%).

**Table 1:- Effect of management practices on fruit infestation by number at early fruiting stage**

| Treatment | % fruit infestation by number at early fruiting stage | | | |
|---|---|---|---|---|
| | Total no. of fruit per plot | No. of infested fruit per plot | % fruit infestation | % reduction of fruit infestation over control |
| $T_1$ | 22.33 b | 2.66 d | 11.92 cd | 87.79 |
| $T_2$ | 22.00 b | 2.66 d | 12.14 cd | 87.56 |
| $T_3$ | 14.67 d | 5.33 b | 36.43 b | 62.69 |
| $T_4$ | 21.00 b | 3.33 cd | 15.98 cd | 83.63 |
| $T_5$ | 26.67 a | 1.66 d | 6.28 d | 93.56 |
| $T_6$ | 17.67 c | 4.33 bc | 24.51 bc | 74.90 |
| $T_7$ | 25.67 a | 2.00 d | 7.81 d | 92.00 |
| $T_8$ | 15.00 d | 5.33 b | 35.81 b | 63.32 |
| $T_9$ | 12.00 e | 11.67 a | 97.65 a | - |
| $LSD_{(0.05)}$ | 2.61 | 1.54 | 12.21 | - |
| CV(%) | 5.56 | 14.90 | 18.54 | - |

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT). Here, $T_1$= Setting up of pheromone trap replaced at 1 month interval, $T_2$= Setting up of poison bait trap @ 2 gm Sevin 85 WP mixed with 100 g mashed sweet gourd and 10 ml molasses replaced at 4 days interval, $T_3$= Spraying of spinosad @ 0.08 ml per liter of water at 7 days interval, $T_4$= Bait spray @ 10 ml molasses and 1 ml Malathion mixed with 1 liter of water @ 7 days interval, $T_5$= $T_{1+}$ $T_{2,}$ $T_6$= $T_{1+}$ $T_{3,}$ $T_7$= $T_{1+}$ $T_{4,}$ $T_8$= Spraying of neem oil @ 3 ml neem oil and 10 ml Trix mixed with 1 liter of water @ 7 days interval, $T_9$=Untreated control]

From the above findings it was revealed that the lowest fruit infestation (6.28%) by number was recorded in $T_5$using the pheromone trap along with poison bait trap in the field, where the highest reduction of fruit infestation over control was 93.56%.As a result, the order of efficacy of management practices in terms of fruit infestation reduction is$T_5$>$T_7$>$T_1$>$T_2$>$T_4$>$T_6$>$T_8$>$T_3$>$T_9$.

**4.2 Fruit infestation by number at mid fruiting stage**

Effect of management practices on fruit infestation by number at mid fruiting stage has been shown in Table 2. Significant variations were observed among the treatments in terms of fruit fly infestation on bitter gourd. The highest number of fruit per plot (37.33) was recorded in $T_5$, which was statistically similar with $T_7$ (34.67fruits/plot), followed by $T_1$ (31.00fruits/plot), $T_2$(30.67fruits/plot) and $T_4$ (30.00fruits/plot). On the other hand, the lowest number of fruit per plot (21.00) was recorded in $T_3$, which was statistically similar with $T_9$(20.00fruits/plot). Accordingly, the lowest number of infested fruit per plot (4.66) was recorded in $T_5$, which is statistically similar with $T_7$ (5.00 fruits/plot).

Considering the level of infestation, the lowest fruit infestation (12.51%) by number was recorded from $T_5$, which is statistically similar with $T_7$(14.53%), $T_1$ (22.53%) and $T_2$ (26.06%). On the other hand, the highest fruit infestation by number was recorded in $T_9$ (91.71%).

Considering the reduction of fruit infestation, the highest reduction of fruit infestation over control was observed 86.35% in $T_5$, followed by $T_7$ (84.15%), $T_1$ (75.43%) and $T_2$ (71.58%). Whereas the lowest reduction of fruit infestation over control was observed in $T_3$ (14.87%) and $T_8$ (39%.03).

**Table 2:- Effect of management practices on fruit infestation by number at mid fruiting stage**

| Treatment | % fruit infestation by number at mid fruiting stage | | | |
|---|---|---|---|---|
| | Total no. of fruit per plot | No. of infested fruit per plot | % fruit infestation | % reduction of fruit infestation over control |
| $T_1$ | 31.00 b | 7.00 cd | 22.53 de | 75.43 |
| $T_2$ | 30.67 b | 8.00 cd | 26.06 de | 71.58 |
| $T_3$ | 21.00 d | 16.33 ab | 78.07 b | 14.87 |
| $T_4$ | 30.00 b | 9.33 c | 31.06 d | 66.13 |
| $T_5$ | 37.33 a | 4.67 d | 12.51 e | 86.35 |
| $T_6$ | 26.67 c | 13.00 b | 48.72 c | 46.87 |
| $T_7$ | 34.67 a | 5.00 d | 14.53 e | 84.15 |
| $T_8$ | 24.00 c | 13.33 b | 55.91 c | 39.03 |
| $T_9$ | 20.00 d | 18.33 a | 91.71 a | - |
| $LSD_{(0.05)}$ | 2.89 | 3.40 | 13.29 | - |
| CV(%) | 4.27 | 13.49 | 13.16 | - |

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT). Here, $T_1$= Setting up of pheromone trap replaced at 1 month interval, $T_2$= Setting up of poison bait trap @ 2 gm Sevin 85 WP mixed with 100 g mashed sweet gourd and 10 ml molasses replaced at 4 days interval, $T_3$= Spraying of spinosad @ 0.08 ml per liter of water at 7 days interval, $T_4$= Bait spray @ 10 ml molasses and 1 ml Malathion mixed with 1 liter of water @ 7 days interval, $T_5$= $T_{1+}$ $T_2$, $T_6$= $T_{1+}$ $T_3$, $T_7$= $T_{1+}$ $T_4$, $T_8$= Spraying of neem oil @ 3 ml neem oil and 10 ml Trix mixed with 1 liter of water @ 7 days interval, $T_9$=Untreated control]

From the above findings it was revealed that the lowest fruit infestation (12.51%) by number was recorded in $T_5$using the pheromone trap along with poison bait trap in the field,where the highest reduction of fruit infestation over control was86.35%. As a result, the order of efficacy of management practices in terms of fruit infestation reduction is$T_5>T_7>T_1>T_2>T_4>T_6>T_8>T_3>T_9$.

### 4.3 Fruit infestation by number at late fruiting stage

Effect of management practices on fruit infestation by number at late fruiting stage has been shown in Table 3. Significant variations were observed among the treatments in terms of fruit fly infestation on bitter gourd. The highest number of fruit per plot (27.00) was recorded in $T_5$, which is statistically similar with $T_7$ (25.67fruits/plot), followed by $T_1$ (23.33fruits/plot) and $T_2$ (23.00fruits/plot). On the other hand, the lowest number of fruits per plot (14.00) was recorded in $T_9$. Accordingly, the lowest number of infested fruit per plot (3.66) was recorded in $T_5$, that was statistically similar with $T_7$ (5.00 fruits/plot).

Considering the level of infestation, the lowest fruit infestation (13.55%) was recorded in $T_5$, which is statistically similar with $T_7$ (19.52%), followed by $T_2$ (30.47%) and $T_1$ (31.53%). On the other hand, the highest fruit infestation by number was recorded in $T_9$(88.23%).

Considering the reduction of fruit infestation, the highest reduction of fruit infestation over control was observed 84.64% in $T_5$, followed by $T_7$ (77.87%), $T_2$ (65.46%) and $T_1$ (64.26%). Whereas the lowest reduction of fruit infestation over control was observed in $T_3$ (33.99%) and $T_6$ (31.80%).

**Table 3:- Effect of management practices on fruit infestation by number at late fruiting stage**

| Treatment | % fruit infestation by number at late fruiting stage | | | |
|---|---|---|---|---|
| | Total no. of fruit per plot | No. of infested fruit per plot | % fruit infestation | % reduction of fruit infestation over control |
| $T_1$ | 23.33 b | 7.33 c | 31.53 cd | 64.26 |
| $T_2$ | 23.00 b | 7.00 cd | 30.47 cd | 65.46 |
| $T_3$ | 15.00 d | 8.67 bc | 58.24 b | 33.99 |
| $T_4$ | 19.67 c | 8.00 bc | 41.31 c | 53.17 |
| $T_5$ | 27.00 a | 3.67 e | 13.55 e | 84.64 |
| $T_6$ | 16.67 cd | 10.00 b | 60.17 b | 31.80 |
| $T_7$ | 25.67 ab | 5.00 de | 19.52 de | 77.87 |
| $T_8$ | 15.00 d | 8.67 bc | 57.96 b | 34.30 |
| $T_9$ | 14.00 d | 12.33 a | 88.23 a | - |
| $LSD_{(0.05)}$ | 3.02 | 2.17 | 15.79 | - |
| CV(%) | 6.36 | 11.59 | 14.86 | - |

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT). Here, $T_1$= Setting up of pheromone trap replaced at 1 month interval, $T_2$= Setting up of poison bait trap @ 2 gm Sevin 85 WP mixed with 100 g mashed sweet gourd and 10 ml molasses replaced at 4 days interval, $T_3$= Spraying of spinosad @ 0.08 ml per liter of water at 7 days interval, $T_4$= Bait spray @ 10 ml molasses and 1 ml Malathion mixed with 1 liter of water @ 7 days interval, $T_5$= $T_{1+}$ $T_{2,}$ $T_6$= $T_{1+}$ $T_{3,}$ $T_7$= $T_{1+}$ $T_{4,}$ $T_8$= Spraying of neem oil @ 3 ml neem oil and 10 ml Trix mixed with 1 liter of water @ 7 days interval, $T_9$=Untreated control]

From the above findings it was revealed that the lowest fruit infestation (13.55%) by number was recorded in $T_5$using the setting up of pheromone trap along with poison bait trap in the field,where the highest reduction of fruit infestation over controlwas 84.64%. As a result, theorder of efficacy of management practices in terms of fruit infestation reduction is$T_5>T_7>T_2>T_1>T_4>T_8>T_3>T_6>T_9$.

### 4.4 Fruit infestation by weight at early fruiting stage

The effect of management practices on fruit infestation by weight at early fruiting stage has been shown in Table 4. Significant variations were observed among the treatments in terms of fruit fly infestation on bitter gourd. The highest weight of fruit per (1917 g) plot was recorded in $T_5$,that is statistically similar with$T_7$ (1874.00g/plot), $T_1$ (1776.00g/plot) and $T_2$ (1772.00g/plot). On the other hand, the lowest weight of fruit per plot (765.30g) was recorded in $T_9$,which is statistically different from all other treatments. Accordingly, the lowest weight of infested fruit per plot (213.30g) was recorded in $T_5$,which is statistically similar with $T_7$ (255.30g/plot).

Considering the level of infestation, the lowest fruit infestation (11.12%) by weight was recorded in $T_5$, which is statistically similar with$T_7$ (13.70%), $T_1$ (16.33%) and $T_2$ (16.83%). On the other hand, the highest fruit infestation by weight was recorded in $T_9$ (67.37%), which is statistically different from all other treatments.

Considering the reduction of fruit infestation, the highest reduction of fruit infestation over control was observed 83.49% in $T_5$, followed by $T_7$ (79.66%), $T_1$ (75.76%) and $T_2$ (75.01%). Whereas the lowest reduction of fruit infestation over control was observed in $T_3$ (54.51%) and $T_8$ (58.02%).

**Table 4:- Effect of management practices on fruit infestation by weight at early fruiting stage**

| **Treatment** | **% fruit infestation by weight at early fruiting stage** | | | |
|---|---|---|---|---|
| | **Total wt. of fruit per plot (gm)** | **Wt. of infested fruit per plot (gm)** | **% fruit infestation** | **% reduction of fruit infestation over control** |
| **$T_1$** | 1776.00 ab | 290.00 de | 16.33 ef | 75.76 |
| **$T_2$** | 1772.00 ab | 298.70 de | 16.83 ef | 75.01 |
| **$T_3$** | 1284.00 d | 393.30 b | 30.64 b | 54.51 |
| **$T_4$** | 1608.00 bc | 330.70 cd | 20.60 de | 69.42 |
| **$T_5$** | 1917.00 a | 213.30 f | 11.12 f | 83.49 |
| **$T_6$** | 1515.00 c | 358.70 bc | 23.73 cd | 64.77 |
| **$T_7$** | 1874.00 a | 255.30 ef | 13.70 f | 79.66 |
| **$T_8$** | 1305.00 d | 366.00 bc | 28.28 bc | 58.02 |
| **$T_9$** | 765.30 e | 513.00 a | 67.37 a | - |
| **$LSD_{(0.05)}$** | 189.60 | 53.25 | 5.57 | - |
| **CV(%)** | 5.18 | 6.66 | 9.19 | - |

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT). Here, $T_1$= Setting up of pheromone trap replaced at 1 month interval, $T_2$= Setting up of poison bait trap @ 2 gm Sevin 85 WP mixed with 100 g mashed sweet gourd and 10 ml molasses replaced at 4 days interval, $T_3$= Spraying of spinosad @ 0.08 ml per liter of water at 7 days interval, $T_4$= Bait spray @ 10 ml molasses and 1 ml Malathion mixed with 1 liter of water @ 7 days interval, $T_5$= $T_{1+}$ $T_{2,}$ $T_6$= $T_{1+}$ $T_{3,}$ $T_7$= $T_{1+}$ $T_{4,}$ $T_8$= Spraying of neem oil @ 3 ml neem oil and 10 ml Trix mixed with 1 liter of water @ 7 days interval, $T_9$=Untreated control]

From the above findings it was revealed that the lowest fruit infestation (11.12%) by weight was recorded in $T_5$, using the pheromone trap along with poison bait trap in the field, where the highest reduction of fruit infestation over control was 83.49%. As a result, the order of efficacy of management practices in terms of fruit infestation reduction is $T_5>T_7>T_1>T_2>T_4>T_6>T_8>T_3>T_9$.

**4.5 Fruit infestation by weight at mid fruiting stage**

The effect of management practices on fruit infestation by weight at mid fruiting stage has been shown in Table 5. Significant variations were observed among the treatments in terms of fruit fly infestation on bitter gourd. The highest weight of fruit per plot (4130.00 g) was recorded in $T_5$that is statistically similar with $T_7$ (3927.00g/plot), followed by $T_1$ (3338.00g/plot), $T_2$ (3322.00g/plot) and $T_4$ (3108.00g/plot). On the other hand, the lowest weight of fruit per plot (1460.00g) was recorded in $T_9$, which is statistically different from all other treatments. Accordingly, the lowest weight of infested fruit per plot (374.70 g)was recorded in $T_5$, which is statistically similar with $T_1$ (525.00 g), $T_2$ (522.30 g) and $T_7$ (486.70 g).

Considering the level of infestation, the lowest fruit infestation (9.13%) by weight was recorded in $T_5$, which is statistically similar with $T_7$ (12.42%), followed by $T_1$ (15.69%) and $T_2$ (15.74%). On the other hand, the highest fruit infestation by weight was recorded in $T_9$ (80.60%).

Considering the reduction of fruit infestation, the highest reduction of fruit infestation over control was observed 88.66% in $T_5$, followed by $T_7$ (84.59%), $T_1$ (80.53%) and $T_2$ (80.47%). Whereas the lowest reduction of fruit infestation over control was observed in $T_3$ (54.50%) and $T_8$ (62.85%).

**Table 5:- Effect of management practices on fruit infestation by weight at mid fruiting stage**

| Treatment | % fruit infestation by weight at mid fruiting stage | | | |
|---|---|---|---|---|
| | Total wt. of fruit per plot | Wt. of infested fruit per plot | % fruit infestation | % reduction of fruit infestation over control |
| $T_1$ | 3338.00 b | 525.00 cde | 15.69 ef | 80.53 |
| $T_2$ | 3322.00 b | 522.30 cde | 15.74 ef | 80.47 |
| $T_3$ | 2150.00 d | 787.70 b | 36.67 b | 54.50 |
| $T_4$ | 3108.00 bc | 579.70 cd | 18.67 de | 76.83 |
| $T_5$ | 4130.00 a | 374.70 e | 9.137 g | 88.66 |
| $T_6$ | 2891.00 c | 663.30 bcd | 22.96 d | 71.51 |
| $T_7$ | 3927.00 a | 486.70 de | 12.42 fg | 84.59 |
| $T_8$ | 2339.00 d | 698.70 bc | 29.94 c | 62.85 |
| $T_9$ | 14600 e | 1176.00 a | 80.60 a | - |
| $LSD_{(0.05)}$ | 372.30 | 172.70 | 4.83 | - |
| CV(%) | 5.27 | 11.21 | 7.54 | - |

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT). Here, $T_1$= Setting up of pheromone trap replaced at 1 month interval, $T_2$= Setting up of poison bait trap @ 2 gm Sevin 85 WP mixed with 100 g mashed sweet gourd and 10 ml molasses replaced at 4 days interval, $T_3$= Spraying of spinosad @ 0.08 ml per liter of water at 7 days interval, $T_4$= Bait spray @ 10 ml molasses and 1 ml Malathion mixed with 1 liter of water @ 7 days interval, $T_5= T_{1+} T_2$, $T_6= T_{1+} T_3$, $T_7= T_{1+} T_4$, $T_8$= Spraying of neem oil @ 3 ml neem oil and 10 ml Trix mixed with 1 liter of water @ 7 days interval, $T_9$=Untreated control]

From the above findings it was revealed that the lowest fruit infestation (9.13%) by weight was recorded in $T_5$using the pheromone trap along with poison bait trap in the field, where the highest reduction of fruit infestation over control was 88.66%.As a result, the order of efficacy of management practices in terms of fruit infestation reduction is$T_5>T_7>T_1>T_2>T_4>T_6>T_8>T_3>T_9$.

**4.6 Fruit infestation by weight at late fruiting stage**

The effect of management practices on fruit infestation by weight at late fruiting stage has been shown in Table 6. Significant variations were observed among the treatments in terms of fruit fly infestation on bitter gourd. The highest weight of fruit per plot (2334.00 g) was recorded in $T_5$, followed by $T_7$ (2057.00g/plot), $T_2$ (1983.00g/plot) and $T_1$ (1957.00g/plot) having no significant difference among them. On the other hand, the lowest weight of fruit per plot (1057.00g) was recorded in $T_9$, which is statistically different from all other treatments. Accordingly, the lowest weight of infested fruit per plot (468.30g)was found in $T_5$,that is statistically similar with $T_1$ (570.30g/plot), $T_2$ (564.70g/plot) and $T_7$ (508.00g/plot).

Considering the level of infestation, the lowest fruit infestation (20.09%) by weight was recorded in $T_5$that is statistically similar with $T_7$ (24.64%), which is followed by $T_1$ (29.15%) and $T_2$ (28.51%). On the other hand, the highest fruit infestation by weight was recorded in $T_9$(89.33%).

Considering the reduction of fruit infestation, the highest reduction of fruit infestation over control was observed 77.51% in $T_5$, followed by $T_7$ (72.41%),$T_2$ (68.08%) and $T_1$ (67.36%). Whereas the lowest reduction of fruit infestation over control was observed in $T_3$ (36.03%) and $T_8$ (38.18%).

**Table 6:- Effect of management practices on fruit infestation by weight at late fruiting stage**

| Treatment | % fruit infestation by weight at late fruiting stage | | | |
|---|---|---|---|---|
| | Total wt. of fruit per plot (gm) | Wt. of infested fruit per plot (gm) | % fruit infestation | % reduction of fruit infestation over control |
| $T_1$ | 1957.00 b | 570.30 cd | 29.15 e | 67.36 |
| $T_2$ | 1983.00 b | 564.70 cd | 28.51 e | 68.08 |
| $T_3$ | 1364.00 d | 779.30 b | 57.14 b | 36.03 |
| $T_4$ | 1657.00 c | 605.30 c | 36.61 d | 59.01 |
| $T_5$ | 2334.00 a | 468.30 d | 20.09 f | 77.51 |
| $T_6$ | 1683.00 c | 723.70 b | 42.92 c | 51.95 |
| $T_7$ | 2057.00 b | 508.00 cd | 24.64 ef | 72.41 |
| $T_8$ | 1360.00 d | 751.00 b | 55.22 b | 38.18 |
| $T_9$ | 1057.00 e | 942.70 a | 89.33 a | - |
| $LSD_{(0.05)}$ | 195.80 | 95.26 | 4.76 | - |
| CV(%) | 4.78 | 6.08 | 4.69 | - |

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT). Here, $T_1$= Setting up of pheromone trap replaced at 1 month interval, $T_2$= Setting up of poison bait trap @ 2 gm Sevin 85 WP mixed with 100 g mashed sweet gourd and 10 ml molasses replaced at 4 days interval, $T_3$= Spraying of spinosad @ 0.08 ml per liter of water at 7 days interval, $T_4$= Bait spray @ 10 ml molasses and 1 ml Malathion mixed with 1 liter of water @ 7 days interval, $T_5$= $T_1$+ $T_2$, $T_6$= $T_1$+ $T_3$, $T_7$= $T_1$+ $T_4$, $T_8$= Spraying of neem oil @ 3 ml neem oil and 10 ml Trix mixed with 1 liter of water @ 7 days interval, $T_9$=Untreated control]

From the above findings it was revealed that the lowest fruit infestation (20.09%) by weight was recorded in $T_5$ using the pheromone trap along with poison bait trap in the field, where the highest reduction of fruit infestation over control was 77.51%. As a result, the order of efficacy of management practices in terms of fruit infestation reduction is $T_5$>$T_7$>$T_2$>$T_1$>$T_4$>$T_6$>$T_8$>$T_3$>$T_9$.

### 4.7 Infestation of edible portion of fruit at different fruiting stage

#### 4.7.1 Early fruiting stage

The effect of management practices on the infestation of edible portion of fruit at early fruiting stage has been shown in Table 7. Significant variations were observed among the treatments in terms of fruit fly infestation on bitter gourd. The lowest infested edible portion of bitter gourd was recorded in $T_5$ (3.88%), that is statistically similar with $T_1$ (7.18%), $T_4$ (6.27%), $T_2$ (5.78%) and $T_7$ (5.21%).

Considering the reduction of infestation on edible portion of bitter gourd, the highest reduction of edible portion infestation over control was observed 94.23% in $T_5$, followed by $T_7$ (92.25%),$T_2$ (91.42%) and $T_4$ (90.68%). Whereas the lowest reduction of edible portion infestation over control was recorded in $T_3$ (67.44%).

From the above findings it was revealed that the lowest edible portion infestation of bitter gourd (3.88%) was recorded in $T_5$ using the pheromone trap along with poison bait trap in the field, where the highest reduction of edible portion infestation over control was94.23%. As a result, the order of efficacy in terms of reducing the infestation of edible portion of fruit at early fruiting stage is $T_5$>$T_7$>$T_2$>$T_4$>$T_1$>$T_5$>$T_8$>$T_6$>$T_3$>$T_9$.

#### 4.7.2 Mid fruiting stage

The effect of management practices on the infestation of edible portion of fruit at mid fruiting stage has been shown in Table 7. Significant variations were observed among the treatments in terms of fruit fly infestation on bitter gourd. The lowest infested edible portion of bitter gourd was recorded in $T_5$ (3.90%), that is statistically similar with $T_7$ (4.76%), $T_1$ (6.42%), $T_2$ (6.65%) and $T_6$ (10.37%).

Considering the reduction of infestation on edible portion of bitter gourd, the highest reduction of edible portion infestation over control was observed 94.48% in $T_5$, followed by $T_7$ (93.27%), $T_1$ (90.92%) and $T_1$ (90.60%). Whereas the lowest reduction of edible portion infestation over control was recorded in $T_8$ (75.06%) and $T_3$ (78.62%).

From the above findings it was revealed that the lowest edible portion infestation of bitter gourd (3.90%) was recorded in $T_5$using the pheromone trap along with poison bait trap in the field, where the highest reduction of edible portion infestation over control was94.48%. As a result, the order of efficacy in terms of reducing the infestation of edible portion of fruit at mid fruiting stage is $T_5>T_7>T_2>T_1>T_2>T_6>T_4>T_3>T_8>T_9$.

**4.7.3 Late fruiting stage**

The effect of management practices on the infestation of edible portion of fruit at late fruiting stage has been shown in Table 7. Significant variations were observed among the treatments in terms of fruit fly infestation on bitter gourd. The lowest infested edible portion of bitter gourd was recorded in $T_5$ (11.46%), that is statistically similar with $T_7$ (14.70%), $T_2$ (12.89%) and $T_1$ (12.32%).

Considering the reduction of infestation on edible portion of bitter gourd, the highest reduction of edible portion infestation over control was observed 85.05% in $T_5$, followed by $T_1$ (83.93%),$T_2$ (83.18%) and $T_7$ (80.82%). Whereas the lowest reduction of edible portion infestation over control was recorded in $T_8$ (58.83%) and $T_3$ (61.56%).

From the above findings it was revealed that the lowest edible portion infestation of bitter gourd (11.46%) was recorded in $T_5$using the pheromone trap along with poison bait trap in the field, where the highest reduction of edible portion infestation over control was85.05%. As a result, the order of efficacy in terms of reducing the infestation of edible portion of fruit at mid fruiting stage is$T_5>T_1>T_2>T_7>T_4>T_6>T_3>T_8>T_9$.

**Table 7:- Effect of management practices on infestation of edible portion of fruit at different fruiting stage**

| Treatment | % infestation of edible portion of fruit | | | | | |
|---|---|---|---|---|---|---|
| | Early fruiting stage | | Mid fruiting stage | | Late fruiting stage | |
| | % infested edible portion | % reduction over control | % infested edible portion | % reduction over control | % infested edible portion | % reduction over control |
| **$T_1$** | 7.18 d | 89.33 | 6.42 de | 90.92 | 12.32 e | 83.93 |
| **$T_2$** | 5.78 d | 91.42 | 6.65 de | 90.60 | 12.89 e | 83.18 |
| **$T_3$** | 21.93 b | 67.44 | 15.14 bc | 78.62 | 29.47 bc | 61.56 |
| **$T_4$** | 6.27 d | 90.68 | 11.61 bcd | 83.60 | 19.55 d | 74.50 |
| **$T_5$** | 3.88 d | 94.23 | 3.90 e | 94.48 | 11.46 e | 85.05 |
| **$T_6$** | 18.89 bc | 71.96 | 10.37 cde | 85.35 | 26.88 c | 64.94 |
| **$T_7$** | 5.21 d | 92.25 | 4.76 de | 93.27 | 14.70 e | 80.82 |
| **$T_8$** | 15.91 c | 76.38 | 17.66 b | 75.06 | 31.56 b | 58.83 |
| **$T_9$** | 67.37 a | - | 70.83 a | - | 76.67 a | - |
| **$LSD_{(0.05)}$** | 5.26 | - | 6.51 | - | 4.03 | - |
| **CV(%)** | 13.03 | - | 16.69 | - | 6.46 | - |

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT). Here, $T_1$= Setting up of pheromone trap replaced at 1 month interval, $T_2$= Setting up of poison bait trap @ 2 gm Sevin 85 WP mixed with 100 g mashed sweet gourd and 10 ml molasses replaced at 4 days interval, $T_3$= Spraying of spinosad @ 0.08 ml per liter of water at 7 days interval, $T_4$= Bait spray @ 10 ml molasses and 1 ml Malathion mixed with 1 liter of water @ 7 days interval, $T_5$= $T_{1+}$ $T_2$, $T_6$= $T_{1+}$ $T_3$, $T_7$= $T_{1+}$ $T_4$, $T_8$= Spraying of neem oil @ 3 ml neem oil and 10 ml Trix mixed with 1 liter of water @ 7 days interval, $T_9$=Untreated control]

### 4.8 Effect of management practices on the yield attributes of bitter gourd

### 4.8.1 Single fruit weight

The effect of management practices on single fruit weight has been shown in Table 8. Significant variations were observed among the treatments in terms of single fruit weight of bitter gourd. The highest single fruit weight (106.30g) was recorded in $T_5$, which is statistically different from all other treatments. That is followed by $T_7$ (96.67g), $T_2$ (93.67g) and $T_1$ (93.33g), having no significant difference among them.

On the other hand, the lowest single fruit weight was recorded in$T_9$ (63.67g) and $T_8$ (65.33g).

Considering the increase of single fruit weight, the maximum increase of single fruit weight over control (66.95%) was observed in $T_5$, which was followed by $T_7$ (51.82%), $T_2$ (47.11%) and $T_1$ (46.58%). Whereas the minimum increase of single fruit weight over control was observed in $T_8$ (2.60%).

From the above findings it was revealed that the highest single fruit weight (106.30g) was recorded in $T_5$ using the pheromone trap along with poison bait trap in the field, where the highest increase of single fruit weight over control was 66.95%.As a result, the order of efficacy in increasing single fruit weight of bitter gourd is $T_5 > T_7 > T_2 > T_1 > T_4 > T_6 > T_3 > T_8 > T_9$.

**4.8.2 Number of fruit per plant**

The effect of management practices on number of fruit per plant has been shown in Table 8. Significant variations were observed among the treatments in terms of number of fruit per plant of bitter gourd. The highest number of fruit per plant (2.41) was recorded in $T_5$, that is statistically similar with $T_7$ (2.05), followed by $T_2$ (1.84) and $T_1$ (1.80). On the other hand, the lowest number of fruit per plant (1.00) was found in $T_9$, that is statistically different from all other treatments.

Considering the increase of number of fruit per plant, the maximum increase of number of fruit per plant over control (141.70%) was observed in $T_5$, followed by $T_7$ (105.00%), $T_2$ (84.30%) and $T_1$ (80.70%). Whereas the minimum increase of number of fruit per plant over control was observed in $T_8$ (39.00%).

From the above findings it was revealed that the highest number of fruit per plant (2.41) was recorded in $T_5$ using the pheromone trap along with poison bait trap in the field, where the highest increase of number of fruit per plant over control was141.70%. As a result, the order of efficacy in increasing number of fruit per plant of bitter gourd is $T_5$>$T_7$>$T_2$> $T_1$> $T_4$> $T_6$> $T_3$> $T_8$> $T_9$.

**Table 8:- Effect of management practices on the yield attributes of bitter gourd**

| Treatment | Single fruit weight per plot (gm) | % increased over control | No. of fruit per plant | % increase d over control |
|---|---|---|---|---|
| $T_1$ | 93.33 b | 46.58 | 1.80 bc | 80.70 |
| $T_2$ | 93.67 b | 47.11 | 1.84 bc | 84.30 |
| $T_3$ | 73.00 d | 14.65 | 1.49 cd | 49.30 |
| $T_4$ | 83.00 c | 30.35 | 1.58 cd | 58.30 |
| $T_5$ | 106.3 a | 66.95 | 2.41 a | 141.70 |
| $T_6$ | 77.00 cd | 20.93 | 1.58 cd | 58.30 |
| $T_7$ | 96.67 b | 51.82 | 2.05 ab | 105.00 |
| $T_8$ | 65.33 e | 2.60 | 1.39 d | 39.00 |
| $T_9$ | 63.67 e | - | 1.00 e | - |
| $LSD_{(0.05)}$ | 7.22 | - | 0.37 | - |
| CV(%) | 3.62 | - | 9.11 | - |

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT). Here, $T_1$= Setting up of pheromone trap replaced at 1 month interval, $T_2$= Setting up of poison bait trap @ 2 gm Sevin 85 WP mixed with 100 g mashed sweet gourd and 10 ml molasses replaced at 4 days interval, $T_3$= Spraying of spinosad @ 0.08 ml per liter of water at 7 days interval, $T_4$= Bait spray @ 10 ml molasses and 1 ml Malathion mixed with 1 liter of water @ 7 days interval, $T_5$= $T_{1+}$ $T_{2,}$ $T_6$= $T_{1+}$ $T_{3,}$ $T_7$= $T_{1+}$ $T_{4,}$ $T_8$= Spraying of neem oil @ 3 ml neem oil and 10 ml Trix mixed with 1 liter of water @ 7 days interval, $T_9$=Untreated control]

### 4.8.2 Length and girth of single healthy fruit

**Length of fruit:** The effect of management practices on length of healthy fruit of bitter gourd has been shown in Table 9. Significant variations were observed among the treatments in terms of length of healthy fruits. The highest length (18.68 cm) of bitter gourd was recorded in $T_5$ (19.74 cm), that is statistically similar with $T_7$. On the other hand the lowest length of healthy bitter gourd was recorded in $T_9$ (14.55 cm).

Considering the increase of fruit length, the maximum increase of bitter gourd length over control (35.60%) was observed in $T_5$, which was followed by $T_7$ (28.32%), $T_1$ (23.26%) and $T_2$ (23.26%). Whereas the minimum increase of fruit length over control was recorded in $T_3$ (9.82%).

From the above findings it was revealed that the highest healthy bitter gourd length (19.74 cm) was recorded in $T_5$ using the pheromone trap along with poison bait trap in the field, where the maximum increase of fruit length over control was 35.60%. As a result, the order of efficacy in increasing healthy bitter gourd length is $T_5$>$T_7$>$T_2$> $T_1$> $T_6$> $T_4$> $T_8$> $T_3$> $T_9$.

**Girth of fruit:** The effect of management practices on girth of healthy fruit of bitter gourd has been shown in Table 9. Significant variations were observed among the treatments in terms of girth of healthy fruits. The highest girth (16.73 cm) of bitter gourd was recorded in $T_5$, that is followed by $T_7$ (14.94 cm). On the other hand the lowest girth of healthy bitter gourd was recorded in $T_9$ (8.95 cm), which is statistically different from all other treatments.

**Table 9:- Effect of management practices on the yield attributes of bitter gourd**

| Treatment | Length of single healthy fruit per plot (cm) | % increase over control | Girth of single healthy fruit per plot (cm) | % increase over control |
|---|---|---|---|---|
| $T_1$ | 17.94 b | 23.26 | 14.24 b | 59.15 |
| $T_2$ | 17.94 b | 23.26 | 13.81 b | 54.41 |
| $T_3$ | 15.98 cd | 9.82 | 11.17 c | 24.80 |
| $T_4$ | 17.30 bc | 18.90 | 13.02 bc | 45.52 |
| $T_5$ | 19.74 a | 35.60 | 16.73 a | 86.97 |
| $T_6$ | 17.41 bc | 19.59 | 14.02 b | 56.68 |
| $T_7$ | 18.68 ab | 28.32 | 14.94 ab | 66.98 |
| $T_8$ | 16.04 cd | 10.17 | 11.59 c | 29.52 |
| $T_9$ | 14.55 d | - | 8.95 d | - |
| $LSD_{(0.05)}$ | 1.587 | - | 1.799 | - |
| CV(%) | 3.85 | - | 5.73 | - |

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT). Here, $T_1$= Setting up of pheromone trap replaced at 1 month interval, $T_2$= Setting up of poison bait trap @ 2 gm Sevin 85 WP mixed with 100 g mashed sweet gourd and 10 ml molasses replaced at 4 days interval, $T_3$= Spraying of spinosad @ 0.08 ml per liter of water at 7 days interval, $T_4$= Bait spray @ 10 ml molasses and 1 ml Malathion mixed with 1 liter of water @ 7 days interval, $T_5$= $T_1$+ $T_2$, $T_6$= $T_1$+ $T_3$, $T_7$= $T_1$+ $T_4$, $T_8$= Spraying of neem oil @ 3 ml neem oil and 10 ml Trix mixed with 1 liter of water @ 7 days interval, $T_9$=Untreated control]

Considering the increase of fruit length, the maximum increase of fruit girth over control (86.97%) was recorded in $T_5$, which was followed by $T_7$ (66.98%), $T_1$ (59.15%) and $T_2$ (54.41%). Whereas the minimum increase of fruit girth over control was observed in $T_3$ (24.80%).

From the above findings it was revealed that the highest healthy bitter gourd girth (19.74 cm) was recorded in $T_5$ using the pheromone trap along with poison bait trap in the field, where the maximum increase of fruit girth over control was 86.97%. As a result, the order of efficacy in increasing the girth of healthy bitter gourd is $T_5$>$T_7$>$T_1$> $T_6$> $T_2$> $T_4$> $T_8$> $T_3$> $T_9$.

### 4.8.3 Length and girth of single infested fruit

**Length of fruit:** The effect of management practices on length of infested fruit of bitter gourd has been shown in Table 9. Significant variations were recorded among the treatments in terms of length of infested fruits. The highest length (14.99 cm) of bitter gourd was recorded in $T_5$, that is statistically similar with $T_7$ (14.19 cm), $T_2$ (13.76) and $T_1$ (13.56 cm). On the other hand the lowest length of infested bitter gourd was recorded in $T_9$ (8.94), which is statistically different from all other treatments.

Considering the increase of fruit length, the maximum percentage of fruit length increase over control (67.69%) was observed in $T_5$, which was followed by $T_7$ (58.60%), $T_2$ (53.97%) and $T_1$ (51.61%). Whereas the minimum percentage of fruit length increase over control was observed in $T_8$ (25.08%).

From the above findings it was revealed that the highest infested fruit length (14.99 cm) was recorded in $T_5$ using the pheromone trap along with poison bait trap in the field, where the maximum increase of fruit length over control was 67.69%. As a result, the order of efficacy in increasing the length of infested bitter gourd is$T_5$>$T_7$>$T_2$> $T_1$> $T_4$> $T_6$> $T_3$> $T_8$> $T_9$.

**Girth of fruit:** The effect of management practices on girth of infested fruit of bitter gourd has been shown in Table 9. Significant variations were observed among the treatments in terms of girth of infested fruits. The highest girth of bitter gourd (13.72 cm)was recorded in $T_5$, that is statistically similar with $T_7$ (12.76 cm), $T_1$ (65.24 cm) and $T_2$ (64.49 cm). On the other hand the lowest girth of infested bitter gourd was recorded in $T_9$ (6.82 cm).

Considering the increase of fruit length, the maximum increase of fruit length over control (100.96%) was recorded in $T_5$, which was followed by $T_7$ (86.82%), $T_1$ (65.24%) and $T_2$ (64.49%). Whereas the minimum increase of fruit length over control was observed in $T_3$ (26.42%).

**Table 10:- Effect of management practices on the yield attributes of bitter gourd**

| Treatment | Length of single infested fruit per plot (cm) | % increase over control | Girth of single infested fruit per plot (cm) | % increase over control |
|---|---|---|---|---|
| **$T_1$** | 13.56 abc | 51.61 | 11.27 ab | 65.24 |
| **$T_2$** | 13.76 ab | 53.97 | 11.22 ab | 64.49 |
| **$T_3$** | 11.27 cd | 26.05 | 8.63 cd | 26.42 |
| **$T_4$** | 12.12 bcd | 35.59 | 9.17 bcd | 34.46 |
| **$T_5$** | 14.99 a | 67.69 | 13.72 a | 100.96 |
| **$T_6$** | 12.07 bcd | 34.94 | 9.47 bc | 38.81 |
| **$T_7$** | 14.19 ab | 58.60 | 12.76 a | 86.82 |
| **$T_8$** | 11.18 d | 25.08 | 9.07 bcd | 32.86 |
| **$T_9$** | 8.94 e | - | 6.82 d | - |
| **$LSD_{(0.05)}$** | 2.154 | - | 2.363 | - |
| **CV(%)** | 7.25 | - | 9.68 | - |

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT). Here, $T_1$= Setting up of pheromone trap replaced at 1 month interval, $T_2$= Setting up of poison bait trap @ 2 gm Sevin 85 WP mixed with 100 g mashed sweet gourd and 10 ml molasses replaced at 4 days interval, $T_3$= Spraying of spinosad @ 0.08 ml per liter of water at 7 days interval, $T_4$= Bait spray @ 10 ml molasses and 1 ml Malathion mixed with 1 liter of water @ 7 days interval, $T_5$= $T_1$+$T_2$, $T_6$= $T_1$+$T_3$, $T_7$= $T_1$+ $T_4$, $T_8$= Spraying of neem oil @ 3 ml neem oil and 10 ml Trix mixed with 1 liter of water @ 7 days interval, $T_9$=Untreated control]

From the above findings it was revealed that the highest infested fruit length (5.40inch) was recorded in $T_5$ using the pheromone trap along with poison bait trap in the field, where the highest increase of fruit length over control was 100.96%. As a result, the order of efficacy in increasing girth of infested bitter gourd is $T_5$>$T_7$>$T_1$> $T_2$> $T_6$> $T_4$> $T_8$> $T_3$> $T_9$.

**4.8.4 Effect on yield of bitter gourd**

The effect of management practices on yield of bitter gourd has been shown in Table 9. Significant variations were observed among the treatments in terms of yield of bitter gourd. The highest yield (9.01 kg/plot) was recorded in $T_5$, which was statistically similar with $T_7$ (8.68 kg/plot), followed by $T_2$ (7.68 kg/plot) and$T_1$ (7.66 kg/plot). On the other hand, the lowest yield (3.42 kg/plot) was recorded in $T_9$, which was statistically different from all other treatments.

Considering the yield of bitter gourd in ton/ha, the highest yield (24.03 ton/ha) was recorded in $T_5$, which was statistically similar with $T_7$ (23.16 ton/ha), followed by $T_2$ (20.50 ton/ha) and$T_1$ (20.45 ton/ha). On the other hand, the lowest yield (9.13 ton/ha) was recorded in $T_9$, which was statistically different from all other treatments.

**Table 11:- Effect of management practices on yield of bitter gourd**

| Treatment | Yield (Kg/plot) | Yield (ton/ha) | % increased over control |
|---|---|---|---|
| **$T_1$** | 7.66 b | 20.45 b | 123.98 |
| **$T_2$** | 7.68 b | 20.50 b | 124.53 |
| **$T_3$** | 5.23 d | 13.96 d | 52.90 |
| **$T_4$** | 6.38 c | 17.02 c | 86.41 |
| **$T_5$** | 9.01 a | 24.03 a | 163.19 |
| **$T_6$** | 6.51 c | 17.37 c | 90.25 |
| **$T_7$** | 8.68 a | 23.16 a | 153.66 |
| **$T_8$** | 5.28 d | 14.08 d | 54.21 |
| **$T_9$** | 3.42 e | 9.13 e | - |
| **$LSD_{(0.05)}$** | 0.81 | 2.16 | - |
| **CV(%)** | 5.11 | 5.11 | - |

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT). Here, $T_1$= Setting up of pheromone trap replaced at 1 month interval, $T_2$= Setting up of poison bait trap @ 2 gm Sevin 85 WP mixed with 100 g mashed sweet gourd and 10 ml molasses replaced at 4 days interval, $T_3$= Spraying of spinosad @ 0.08 ml per liter of water at 7 days interval, $T_4$= Bait spray @ 10 ml molasses and 1 ml Malathion mixed with 1 liter of water @ 7 days interval, $T_5$= $T_{1+}$ $T_{2,}$ $T_6$= $T_{1+}$ $T_{3,}$ $T_7$= $T_{1+}$ $T_{4,}$ $T_8$= Spraying of neem oil @ 3 ml neem oil and 10 ml Trix mixed with 1 liter of water @ 7 days interval, $T_9$=Untreated control]

Considering the yield increase over control, the maximum increase of yield of bitter gourd over control (163.19%) was recorded in $T_5$, which was followed by $T_7$ (153.66%), $T_2$ (124.53%) and $T_1$ (123.98%). Whereas the minimum increase of yield over control (52.90%) was recorded in $T_3$.

From the above findings it was revealed that the highest yield (24.04 ton/ha) was produced in $T_5$ treated plot using the pheromone trap along with poison bait trap in the field, where the highest increase of yield over control was 163.19%. As a result, the order of efficacy of management practices in terms of increasing the yield is $T_5>T_7>T_2>T_1>T_6>T_4>T_8>T_3>T_9$.

### 4.9 Relationship between fruit infestation and yield of bitter gourd

#### 4.9.1 Early fruiting stage

Correlation study was done to establish the relationship between the percent fruit infestation by number at early fruiting stage and yield (t/ha) of bitter gourd during the management of fruit fly. From the study it was revealed that significant correlation was observed between the fruit infestation and yield of bitter gourd (Figure 1). It was evident from the Figure 1 that the regression equation $y = -0.150x + 21.90$ gave a good fit to the data, and the co-efficient of determination ($R^2 = 0.795$) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a negative relationship between fruit infestation and yield of bitter gourd, i.e., the yield decreased with the increase of the infestation of fruit with cucurbit fruit fly at early fruiting stage.

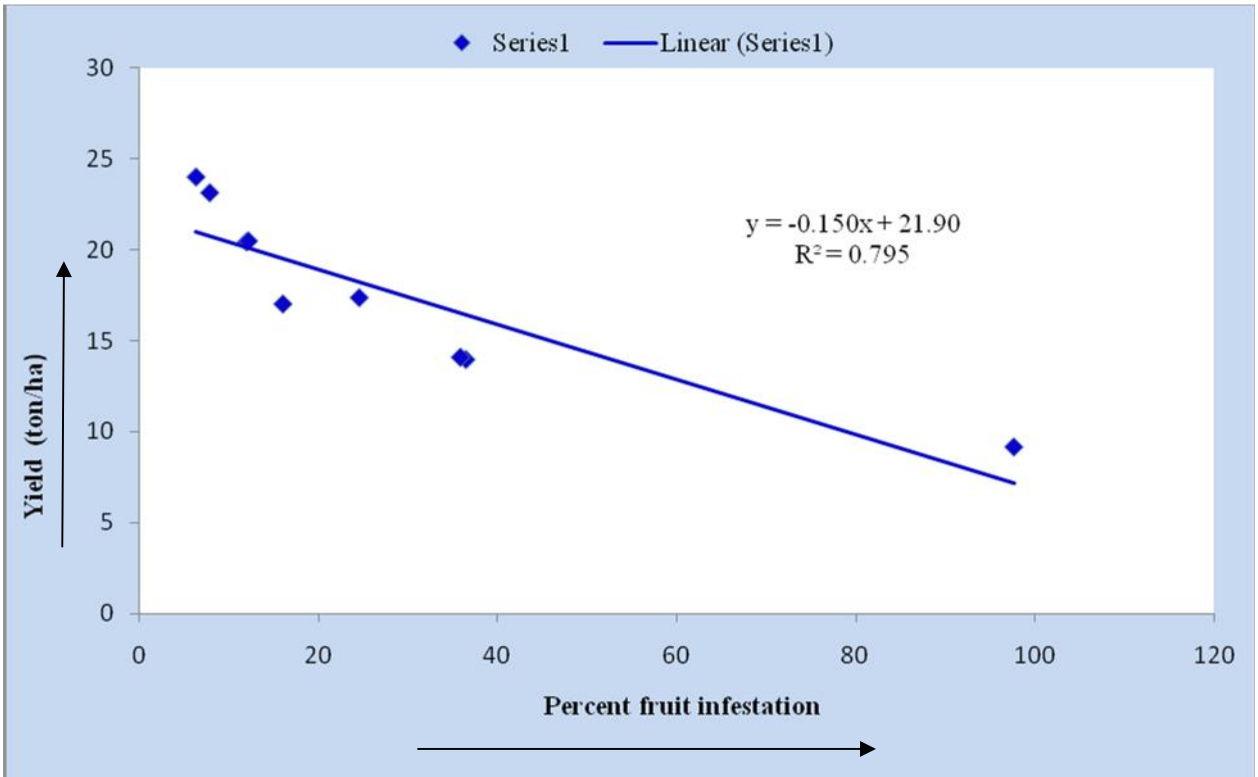


**Figure 1. Relationship between percent fruit infestation by number and yield at early fruiting stage**

### 4.9.2 Mid fruiting stage

Correlation study was done to establish the relationship between the percent fruit infestation by number at mid fruiting stage and yield (t/ha) of bitter gourd during the management of fruit fly. From the study it was revealed that significant correlation was observed between the fruit infestation and yield of bitter gourd (Figure 2). It was evident from the Figure 2 that the regression equation y = -0.163x + 24.64 gave a good fit to the data, and the co-efficient of determination ($R^2$ = 0.910) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a negative relationship between fruit infestation and yield of bitter gourd, i.e., the yield decreased with the increase of the infestation of fruit with cucurbit fruit fly at mid fruiting stage.

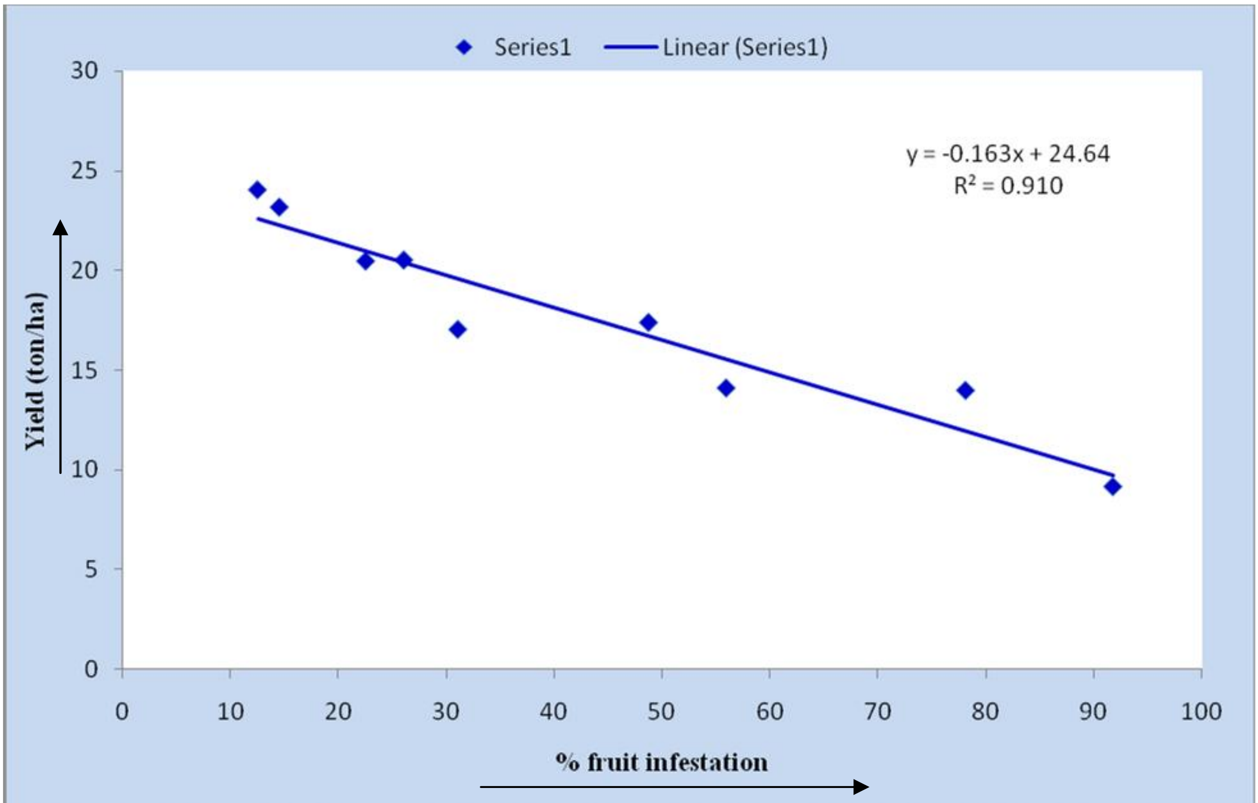


**Figure 2. Relationship between percent fruit infestation by number and yield at mid fruiting stage**

### 4.9.3 Late fruiting stage

Correlation study was done to establish the relationship between the percent fruit infestation by number at late fruiting stage and yield (t/ha) of bitter gourd during the management of fruit fly. From the study it was revealed that significant correlation was observed between the fruit infestation and yield of bitter gourd (Figure 3). It was evident from the Figure 3 that the regression equation y = -0.197x + 26.53 gave a good fit to the data, and the co-efficient of determination ($R^2$ = 0.937) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a negative relationship between fruit infestation and yield of bitter gourd, i.e., the yield decreased with the increase of the infestation of fruit with cucurbit fruit fly at late fruiting stage.

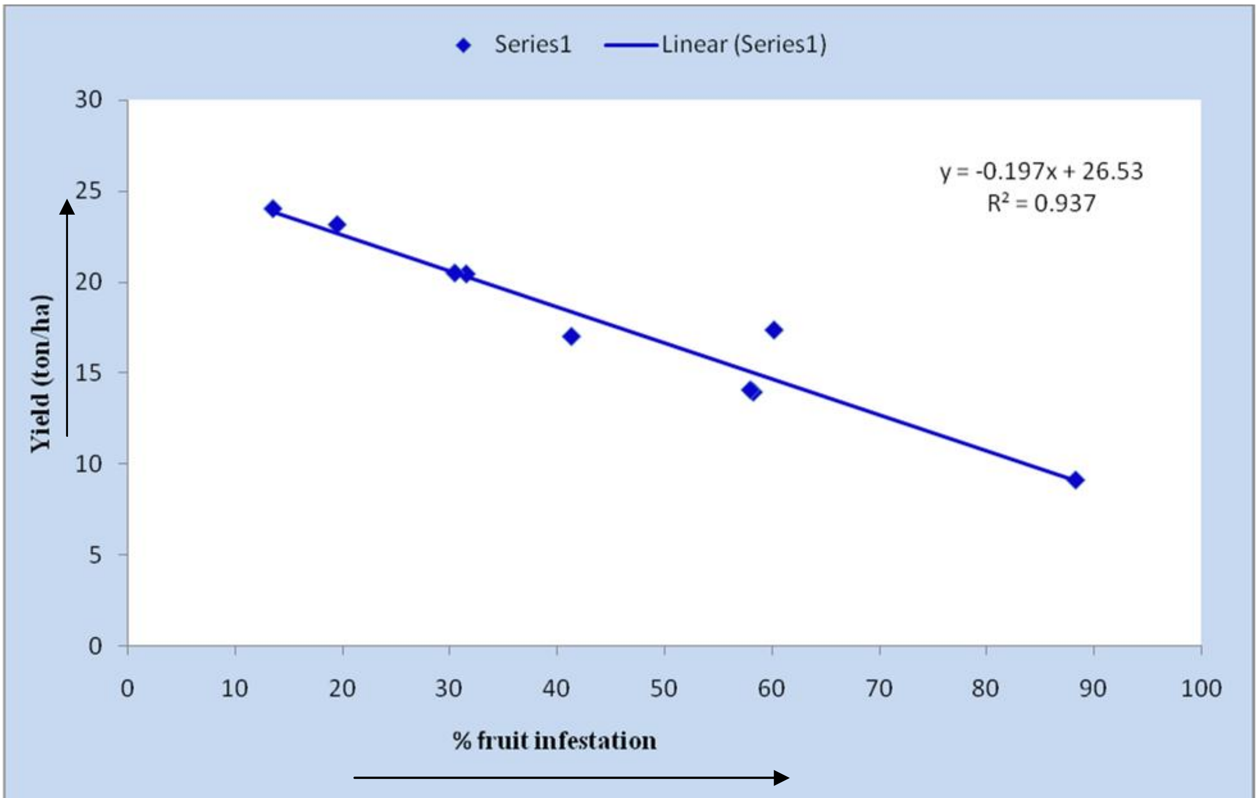


**Figure 3. Relationship between percent fruit infestation by number at late fruiting stage and yield**

### 4.10 Relationship between single fruit weight and yield

Correlation study was done to establish the relationship between the single fruit weight and yield (t/ha) of bitter gourd during the management of fruit fly. From the study it was revealed that significant correlation was observed between the single fruit weight and yield of bitter gourd (Figure 4). It was evident from the Figure 4 that the regression equation y = 0.317x – 8.992 gave a good fit to the data, and the co-efficient of determination ($R^2$ = 0.931) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a positive relationship between single fruit weight and yield of bitter gourd, i.e., the yield increased with the increase of the single fruit weight.

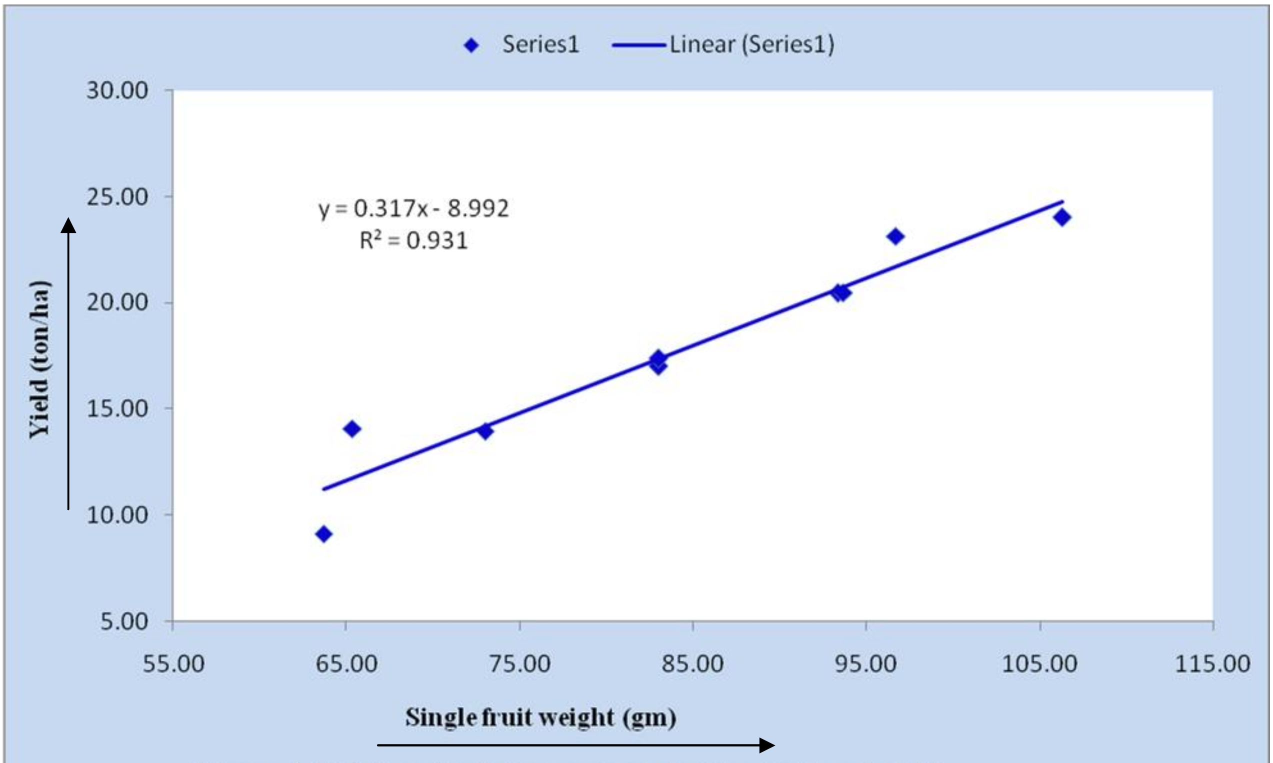


**Figure 4. Relationship between single fruit weight and yield**

**4.11 Relationship between number of fruit per plant and yield**

Correlation study was done to establish the relationship between the number of fruit per plant and yield (t/ha) of bitter gourd during the management of fruit fly. From the study it was revealed that significant correlation was observed between the number of fruit per plant and yield of bitter gourd (Figure 5). It was evident from the Figure 5 that the regression equation y = 11.46x – 1.572 gave a good fit to the data, and the co-efficient of determination ($R^2$ = 0.932) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis it was evident that there was a positive relationship between number of fruit per plant and the yield of bitter gourd, i.e., the yield increased with the increase of the number of fruit per plant.

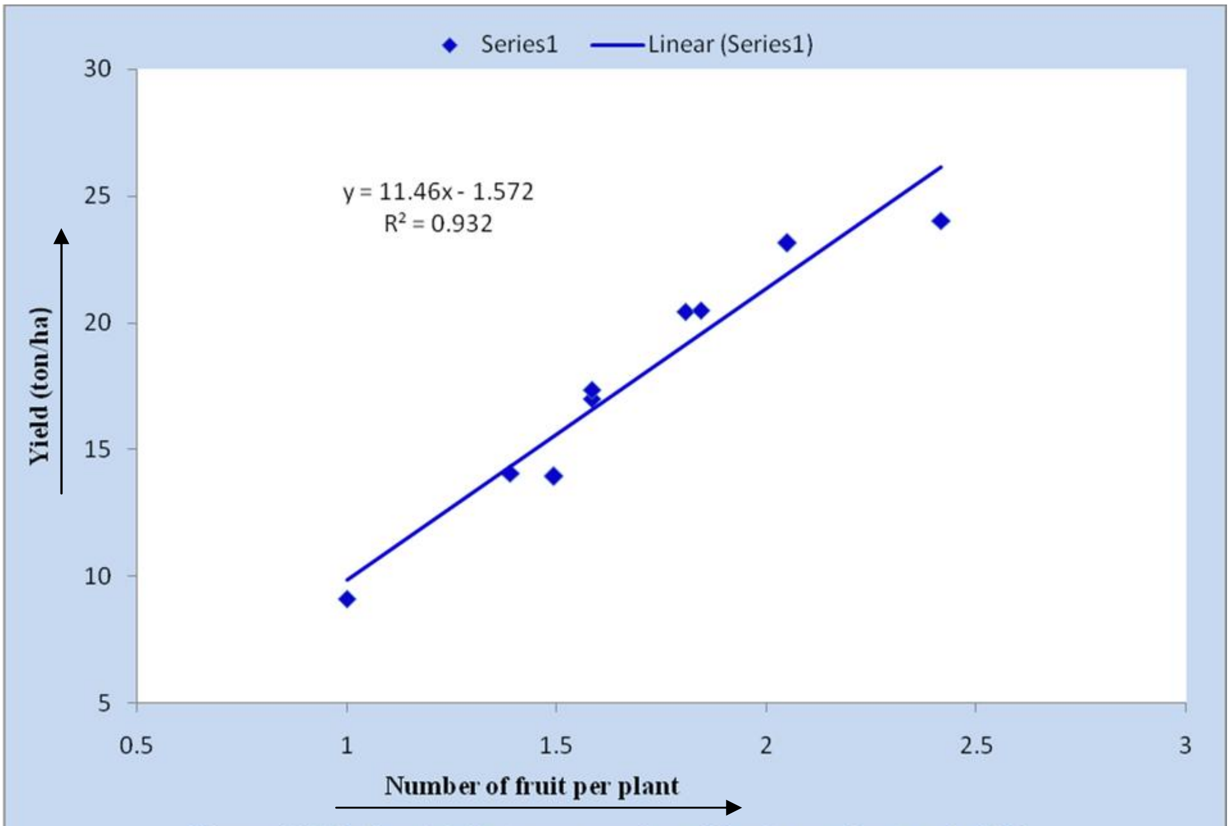


Figure 5. Relationship between number of fruit per plant and yield

**4.12 Relationship between length of single fruit and yield**

Correlation study was done to establish the relationship between the length of single fruit and yield (t/ha) of bitter gourd during the management of fruit fly. From the study it was revealed that significant correlation was observed between the length of single fruit and yield of bitter gourd (Figure 6). It was evident from the Figure 6 that the regression equation y = 7.737x – 34.91 gave a good fit to the data, and the co-efficient of determination ($R^2$ = 0.972) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis it was evident that there was a positive relationship between length of single fruit and yield of bitter gourd, i.e., the yield increased with the increase of the length of single fruit.

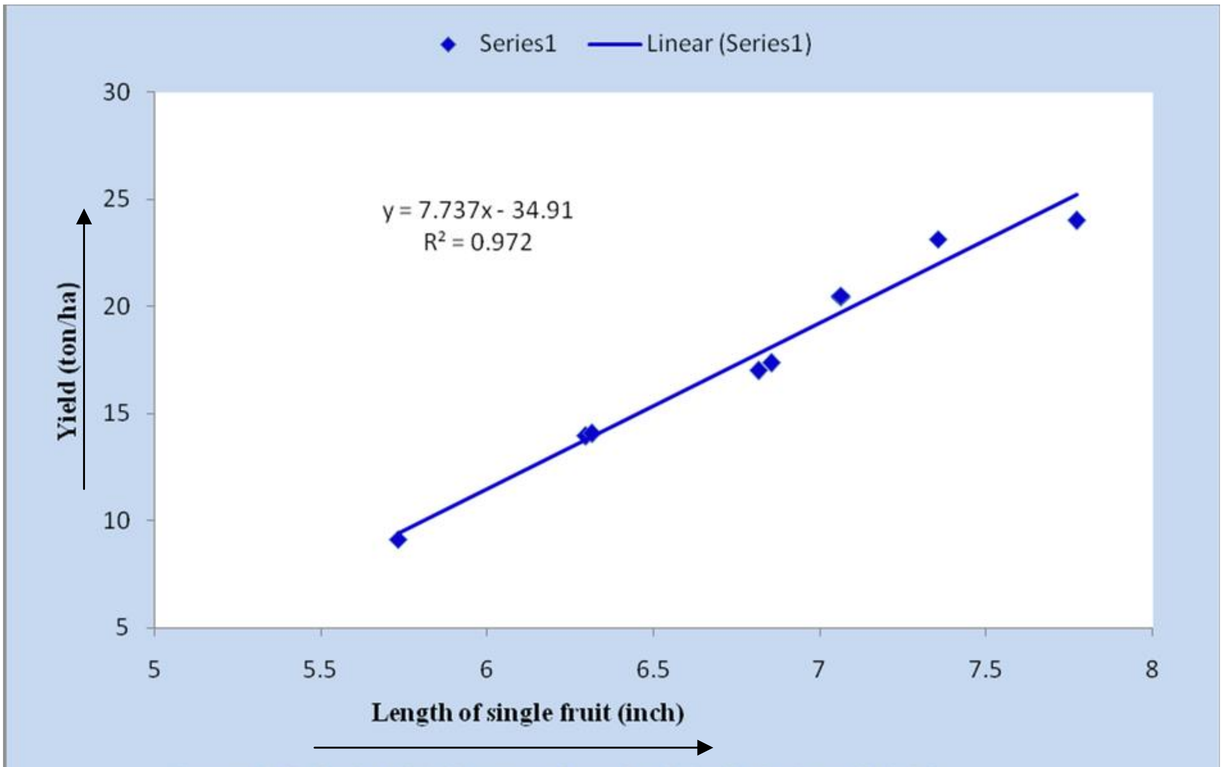


**Figure 6. Relationship between length of single fruit and yield**

**4.13 Relationship between girth of single healthy fruit and yield**

Correlation study was done to establish the relationship between the girth of single fruit and yield (t/ha) of bitter gourd during the management of fruit fly. From the study it was revealed that significant correlation was observed between the girth of single healthy fruit and yield of bitter gourd (Figure 7). It was evident from the Figure 7 that the regression equation y = 5.155x – 8.977 gave a good fit to the data, and the co-efficient of determination ($R^2$ = 0.938) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis it was evident that there was a positive relationship between girth of single fruit and yield of bitter gourd, i.e., the yield increased with the increase of the girth of single fruit.

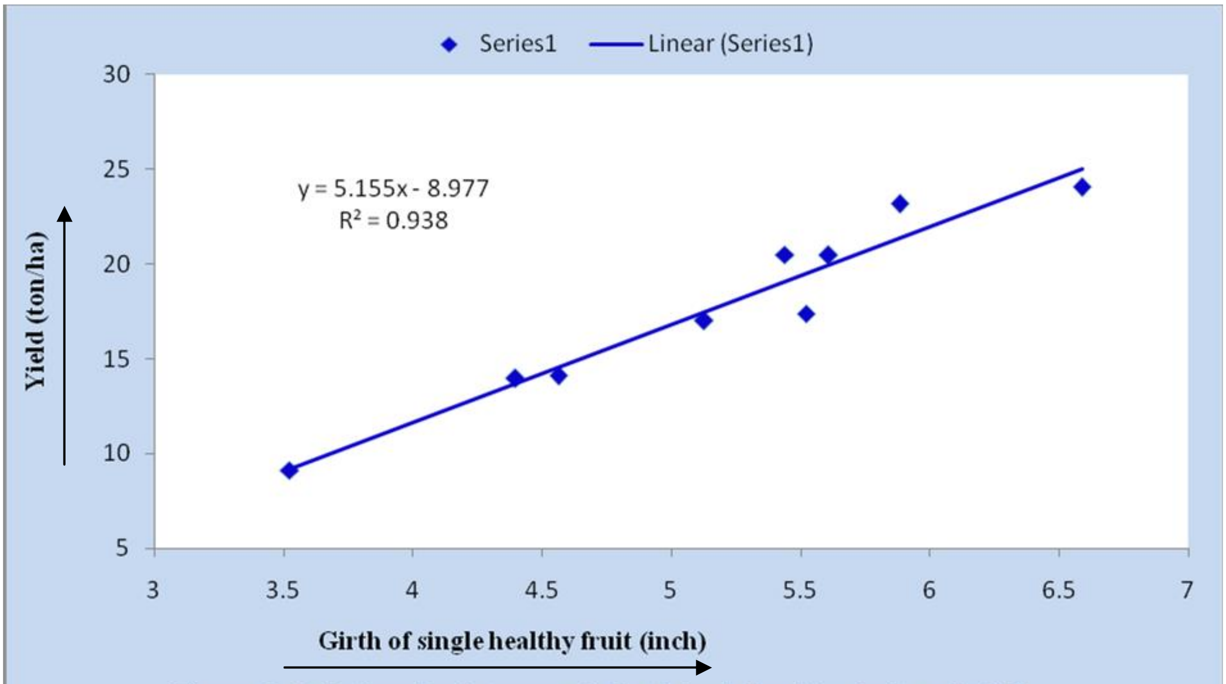


**Figure 7. Relationship between girth of single healthy fruit and yield**

**4.14 Adult fruit fly captured in bait traps and pheromone traps**

The efficacy of pheromone trap as compared with poison bait trap in terms of capturing number of adult fruit flies had been assessed in this study. The data as depicted in the Figure 8 represented that more or less higher number of adult fruit flies had been captured in poison bait trap than pheromone trap throughout the cropping season of bitter gourd. From the comparative study it was observed that the average number of adult fruit flies captured in pheromone traps ranged from 6.25 to 24.33 fruit flies/trap, whereas the average number of adult fruit flies captured in poison bait trap ranged from 25.83 to 43.17 fruit flies/trap. Considering the overall average fruit fly captured, the number of adult fruit flies captured was much higher (32.60 fruit flies/trap) in poison bait trap than that of pheromone trap (17.49 fruit flies/trap).

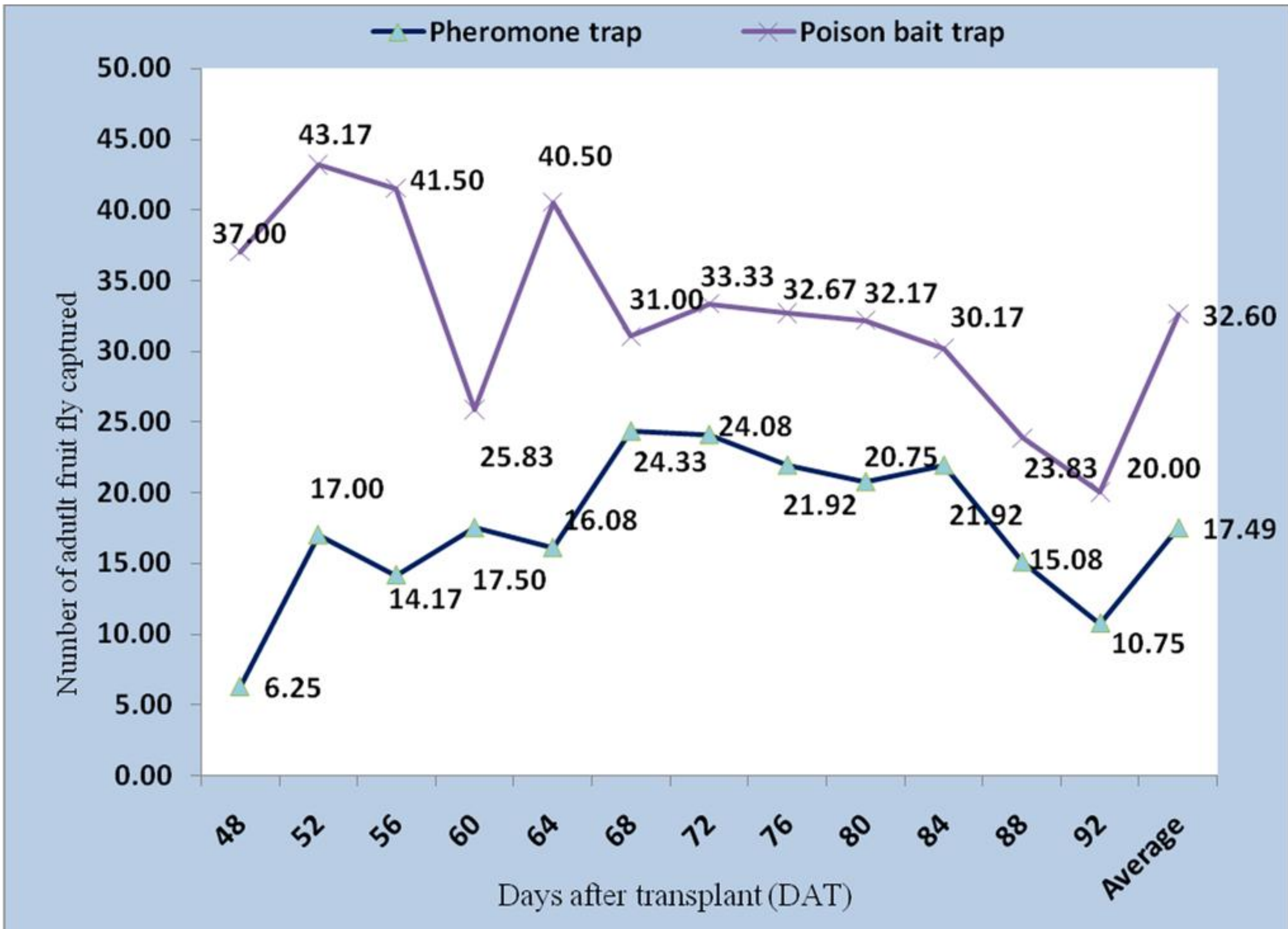


**Figure 8. Number of adult fruit fly captured in pheromone trap and poison bait trap**

**4.15 Reasons for variations of number of fruit fly captured in poison bait trap**

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

In depth analysis was done to find out the above mentioned reasons for variations of adult fruit fly capture in poison bait traps. From the data represent in the Table 1, 2 and 3, it was revealed that at early fruit and late fruit stage of the cropping season, the lower number of fruits of bitter gourd was produced. Thus the incidence of less number of adult fruit flies might be occurred to attack fruit flies than that of mid fruiting stage of bitter gourd. That’s why the less number of fruit flies might be captured in the poison bait.

On the other hand, the temperature variation throughout the data recording time was ranged from 29.5 to 35.0°C, of which the highest temperature (35.0°C) was recorded at 60 DAT and lowest temperature (29.5°C) was recorded at 64 DAT (Figure 9). This highest temperature might be responsible for drying up of the materials kept in poison bait traps. That’s why the less number of adult fruit flies was captured in poison bait trap at 60 DAT, but this highest temperature did not affect the number of fruit fly captured in pheromone trap. On the other hand, the lower temperature at 64 DAT might be responsible for higher number of adult fruit flies per trap due to presence of more suitable temperature for fruit flies.

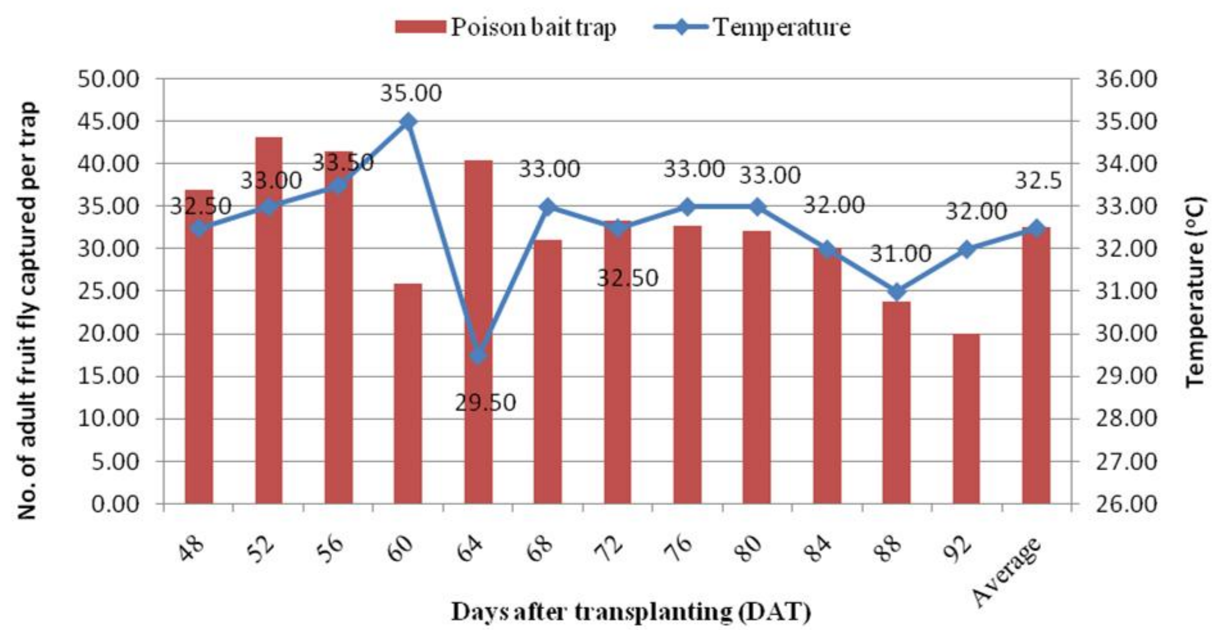


**Figure 9. Relationship between number of adult fruit fly captured in poison bait trap and temperature**

From the above findings it was revealed that poison bait trap was more effective than pheromone trap in terms of capturing adult fruit fly throughout the cropping season, where in case of poison bait trap the average number of adult fruit flies captured per trap was 32.6 and in case of pheromone trap this number was 17.49 fruit flies per trap. The higher temperature (35°C) negatively affected the capturing of adult fruit fly for poison bait trap because of drying up of bait materials, but not affected on the adult capturing capacity of pheromone trap.

### 4.15 Economic analysis of different management practices applied against cucurbit fruit fly infesting bitter gourd

Economic analysis of different management practices applied against cucurbit fruit fly infestation on bitter gourd presented in Table 12. The untreated control ($T_9$) did not incur any pest management cost. The labor costs were involved in $T_1$, $T_2$, $T_3$, $T_4$, $T_5$, $T_6$, $T_7$ and $T_8$ for applying treatments in the experimental plots (Appendix III). From the economic analysis, it was revealed that the highest benefit cost ratio (BCR) (118.45) was calculated in $T_5$ (Pheromone trap along with poison bait trap), where the total adjusted net return was counted as benefit. This was followed (100.9) by $T_2$ (Poison bait trap) and99.0 in $T_1$ (Pheromone trap). The minimum BCR (34.17) was calculated in $T_8$ (3 ml neem oil and 10 ml trix mixed with 1 liter of water@ 7 days interval).

**Table 12:- Economic analysis of different management practices applied against cucurbit fruit fly in bitter gourd during Kharif I, 2016 at Dhaka**

| Treatments | Cost of Management (Tk.) | Yield (kg/ha) | Gross return (Tk.) | Net Return (Tk.) | Adjusted net return (Tk.) | BCR |
|---|---|---|---|---|---|---|
| **$T_1$** | 6396.00 | 20450 | 409000 | 402604 | 220004 | 34.39 |
| **$T_2$** | 6346.80 | 20500 | 410000 | 403654 | 221054 | 34.83 |
| **$T_3$** | 5111.00 | 13960 | 279200 | 274089 | 91489 | 17.90 |
| **$T_4$** | 6089.00 | 17020 | 340400 | 334311 | 151711 | 24.92 |
| **$T_5$** | 6742.00 | 24030 | 480600 | 473858 | 291258 | 43.20 |
| **$T_6$** | 5507.00 | 17370 | 347400 | 341893 | 159293 | 28.93 |
| **$T_7$** | 6485.33 | 23160 | 463200 | 456715 | 274115 | 42.27 |
| **$T_8$** | 6222.22 | 14080 | 281600 | 275377.78 | 92777.78 | 14.91 |
| **$T_9$** | 0.00 | 9130 | 182600 | 182600 | 0 | - |

[$T_1$=Pheromone trap (Cue-lure + soap; @ 4 days interval) , $T_2$=Poison bait trap(2 gm Sevin 85 WP + 100 gm Mashed Sweet Gourd + 10 ml Molasses; @ 4 days interval), $T_3$=Spinosad(0.08 ml per liter of water @ 7 days interval), $T_4$=Bait spray (1L water + 10 ml Molasses + 1 ml Malathion @ 7 days interval), $T_5$= $T_{1+}$ $T_{2,}$ $T_6$= $T_{1+}$ $T_{3,}$ $T_7$= $T_{1+}$ $T_{4,}$ $T_8$=Neem oil (3 ml Neem Oil + 10 ml Trix + 1 L Water @ 7 days interval), $T_9$=Untreated control]

Wholesale price of bitter gourd at that time, 1 Kg = 20 Tk.

# CHAPTER V

# SUMMARY AND CONCLUSION

Ecofriendly management of cucurbit fruit fly on bitter gourd was investigated at the field laboratory of the Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during the period from February, 2016 to June, 2016. The treatments were $T_1$ comprised of setting up of pheromone trap replaced at 1 month interval, $T_2$ comprised of setting up of poison bait trap @ 2 gm Sevin 85 WP mixed with 100 g mashed sweet gourd and 10 ml molasses replaced at 4 days interval, $T_3$ comprised of spraying of spinosad @ 0.08 ml per liter of water at 7 days interval, $T_4$ comprised of bait spray @ 10 ml molasses and 1 ml Malathion mixed with 1 liter of water @ 7 days interval, $T_5$ comprised of $T_1$ and $T_2$; $T_6$ comprised of $T_1$ and $T_3$; $T_7$ comprised of $T_1$ and $T_4$; $T_8$ comprised of spraying of neem oil @ 3 ml neem oil and 10 ml Trix mixed with 1 liter of water @ 7 days interval, $T_9$ comprised of untreated control. Data on fruit infestation by number and weight and yield contributing characters and yield were recorded including benefit cost ratio (BCR) of different management practices applied against fruit fly on bitter gourd.

Considering the effect of different management practices in reducing the level of infestation by fruit fly on bitter gourd, at early harvesting stage of bitter gourd, the lowest fruit infestation (6.28%) by number was recorded in $T_5$ using the pheromone trap along with poison bait trap in the field, where the highest reduction of fruit infestation over control was 93.56%. As a result, the order of efficacy of management practices in terms of fruit infestation reduction is $T_5>T_7>T_1>T_2>T_4>T_6>T_8>T_3>T_9$. At mid harvesting stage of bitter gourd, the lowest fruit infestation (12.51%) by number was recorded in $T_5$ using the pheromone trap along with poison bait trap in the field, where the highest reduction of fruit infestation over control was 86.35%. As a result, the order of efficacy of management practices in terms of fruit infestation reduction is $T_5>T_7>T_1>T_2>T_4>T_6>T_8>T_3>T_9$. At late harvesting stage of bitter gourd, the lowest fruit infestation (13.55%) by number was recorded in $T_5$using the setting up of pheromone trap along with poison bait trap in the field, where the highest reduction of fruit infestation over control was 84.64%. As a result, the order of efficacy of management practices in terms of fruit infestation reduction is$T_5>T_7>T_2>T_1>T_4>T_8>T_3>T_6>T_9$.

At early harvesting stage of bitter gourd, the lowest fruit infestation (11.12%) by weight was recorded in $T_5$, using the pheromone trap along with poison bait trap in the field, where the highest reduction of fruit infestation over control was 83.49%. As a result, the order of efficacy of management practices in terms of fruit infestation reduction is $T_5>T_7>T_1>T_2>T_4>T_6>T_8>T_3>T_9$. At mid harvesting stage of bitter gourd, the lowest fruit infestation (9.13%) by weight was recorded in $T_5$using the pheromone trap along with poison bait trap in the field, where the highest reduction of fruit infestation over control was 88.66%.As a result, the order of efficacy of management practices in terms of fruit infestation reduction is$T_5>T_7>T_1>T_2>T_4>T_6>T_8>T_3>T_9$. At late harvesting stage of bitter gourd, the lowest fruit infestation (20.09%) by weight was recorded in $T_5$ using the pheromone trap along with poison bait trap in the field, where the highest reduction of fruit infestation over control was 77.51%. As a result, the order of efficacy of management practices in terms of fruit infestation reduction is $T_5>T_7>T_2>T_1>T_4>T_6>T_8>T_3>T_9$.

At early harvesting stage of bitter gourd, that the lowest edible portion infestation of bitter gourd (3.88%) was recorded in $T_5$using the pheromone trap along with poison bait trap in the field, where the highest reduction of edible portion infestation over control was94.23%. As a result, the order of efficacy in terms of reducing the infestation of edible portion of fruit at early fruiting stage is $T_5$>$T_7$>$T_2$>$T_4$>$T_1$>$T_5$>$T_8$>$T_6$>$T_3$>$T_9$. At mid harvesting stage of bitter gourd, the lowest edible portion infestation of bitter gourd (3.90%) was recorded in $T_5$ using the pheromone trap along with poison bait trap in the field, where the highest reduction of edible portion infestation over control was 94.48%. As a result, the order of efficacy in terms of reducing the infestation of edible portion of fruit at mid fruiting stage is $T_5$>$T_7$>$T_2$>$T_1$>$T_2$>$T_6$>$T_4$>$T_3$>$T_8$>$T_9$. At late harvesting stage of bitter gourd, the lowest edible portion infestation of bitter gourd (11.46%)was recorded in $T_5$ using the pheromone trap along with poison bait trap in the field, where the highest reduction of edible portion infestation over control was 85.05%. As a result, the order of efficacy in terms of reducing the infestation of edible portion of fruit at mid fruiting stage is $T_5$>$T_1$>$T_2$>$T_7$>$T_4$>$T_6$>$T_3$>$T_8$>$T_9$.

The highest single fruit weight (106.30g) was recorded in $T_5$ using the pheromone trap along with poison bait trap in the field, where the highest increase of single fruit weight over control was 66.95%.As a result, the order of efficacy in increasing single fruit weight of bitter gourd is $T_5$>$T_7$>$T_2$> $T_1$> $T_4$> $T_6$> $T_3$> $T_8$> $T_9$.

The highest number of fruit per plant (2.41) was recorded in $T_5$ using the pheromone trap along with poison bait trap in the field, where the highest increase of number of fruit per plant over control was141.70%. As a result, the order of efficacy in increasing number of fruit per plant of bitter gourd is $T_5$>$T_7$>$T_2$> $T_1$> $T_4$> $T_6$> $T_3$> $T_8$> $T_9$.

The highest healthy bitter gourd length (19.74 cm) was recorded in $T_5$ using the pheromone trap along with poison bait trap in the field, where the maximum increase of fruit length over control was 35.60%. As a result, the order of efficacy in increasing healthy bitter gourd length is $T_5$>$T_7$>$T_2$>$T_1$>$T_6$>$T_4$>$T_8$>$T_3$>$T_9$. The highest healthy bitter gourd girth (19.74 cm) was recorded in $T_5$ using the pheromone trap along with poison bait trap in the field, where the maximum increase of fruit girth over control was 86.97%. As a result, the order of efficacy in increasing the girth of healthy bitter gourd is $T_5>T_7>T_1>T_6>T_2>T_4>T_8>T_3>T_9$. The highest infested fruit length (14.99 cm) was recorded in $T_5$using the pheromone trap along with poison bait trap in the field, where the maximum increase of fruit length over control was 67.69%. As a result, the order of efficacy in increasing the length of infested bitter gourd is $T_5>T_7>T_2>T_1>T_4>T_6>T_3>T_8>T_9$. The highest infested fruit length (5.40inch) was recorded in $T_5$using the pheromone trap along with poison bait trap in the field, where the highest increase of fruit length over control was 100.96%. As a result, the order of efficacy in increasing girth of infested bitter gourd is $T_5>T_7>T_1>T_2> T_6>T_4> T_8> T_3> T_9$.

Considering the yield of bitter gourd, the highest yield (24.03 ton/ha) was recorded in $T_5$, which was statistically similar with $T_7$ (23.16 ton/ha), followed by $T_2$ (20.50 ton/ha) and $T_1$ (20.45 ton/ha). On the other hand, the lowest yield (9.13 ton/ha) was recorded in $T_9$, which was statistically different from all other treatments.

In case of relationships between yield attributes and yield of bitter gourd as influenced by different management practices applied against cucurbit fruit fly infesting bitter gourd, the length (r = 0.972), girth (r = 0.938 ), single fruit weight (r = 0.931) and number of fruit per plant (r = 0.932) of the fruit strongly as well as positively correlated to the yield of bitter gourd, i.e., yield of bitter gourd increased with the increase of the length (cm), girth (cm), single fruit weight (g) and number of fruit per plant.

Comparative study revealed that poison bait trap was more effective than pheromone trap in terms of capturing adult fruit fly per trap throughout the cropping season, where in case of poison bait trap the average number of adult fruit flies captured per trap was 32.6 and in case of pheromone trap this number was 17.49 fruit flies per trap. The higher temperature (35$^{o}$C) negatively affected the capturing of adult fruit fly for poison bait trap because of drying up of bait materials, but not affected on the adult capturing capacity of pheromone trap.

The highest benefit cost ratio (BCR) (43.20) was calculated in $T_5$ (Pheromone trap along with poison bait trap), where the total adjusted net return was counted as benefit. This was followed (42.27) by $T_7$ (Pheromone trap along with bait spray). The minimum BCR (14.91) was calculated in $T_8$ (3 ml neem oil and 10 ml trix mixed with 1 liter of water @ 7 days interval).

## CONCLUSION

From the present study, it may be concluded that incidence of cucurbit fruit fly and infestation of bitter gourd by cucurbit fruit fly was significantly varied among the treatments. The overall study revealed that the highest performance was achieved from Pheromone trap along with Poison bait trap ($T_5$). Highest reduction (88%) of fruit infestation over control was achieved by Pheromone trap along with Poison bait trap ($T_5$). Highest yield increase (163%) over control was achieved by Pheromone trap along with Poison bait trap ($T_5$). Highest increase of fruit length (35%) & girth (86%), number of fruit per plant (141%), single fruit weight (106%) over control was achieved by Pheromone trap along with Poison bait trap ($T_5$). Poison bait trap is more effective for capturing adult fruit fly (32.6 adults/trap/4 days) than Pheromone trap (17.49 adults/ trap/4 days). Highest yield (24.03 ton/ha) was achieved by Pheromone trap along with Poison bait trap ($T_5$) followed by 23.16 ton/ha achieved by Pheromone trap along with Bait spray ($T_7$). Highest BCR (43.20) was also achieved by Pheromone trap along with Poison bait trap ($T_5$). Pheromone trap along with Bait spray ($T_7$) also showed similar performance in terms of number of fruit per plant, weight of single fruit, edible portion of infested fruit, length of fruit, girth of fruit and yield. It also reduced fruit infestation. Considering the results of the present study, it can be concluded that Pheromone trap along with Poison bait trap ($T_5$) and Pheromone trap along with Bait spray ($T_7$) may be used for the management of fruit fly attacking cucurbitaceous vegetables.

**Considering the findings of the study the following recommendations can be drawn:**

1. To minimize the use of chemical insecticides in cucurbit fruit fly control programmes, Pheromone trap in combination with Poison bait trap and Pheromone trap in combination with Bait spray can play a significant role. It should be adopted in large scale production of chemical free cucurbitaceous vegetables.
2. Further study of this experiment is needed in different locations of Bangladesh for accuracy of the results obtained from the present experiment.

# CHAPTER VI

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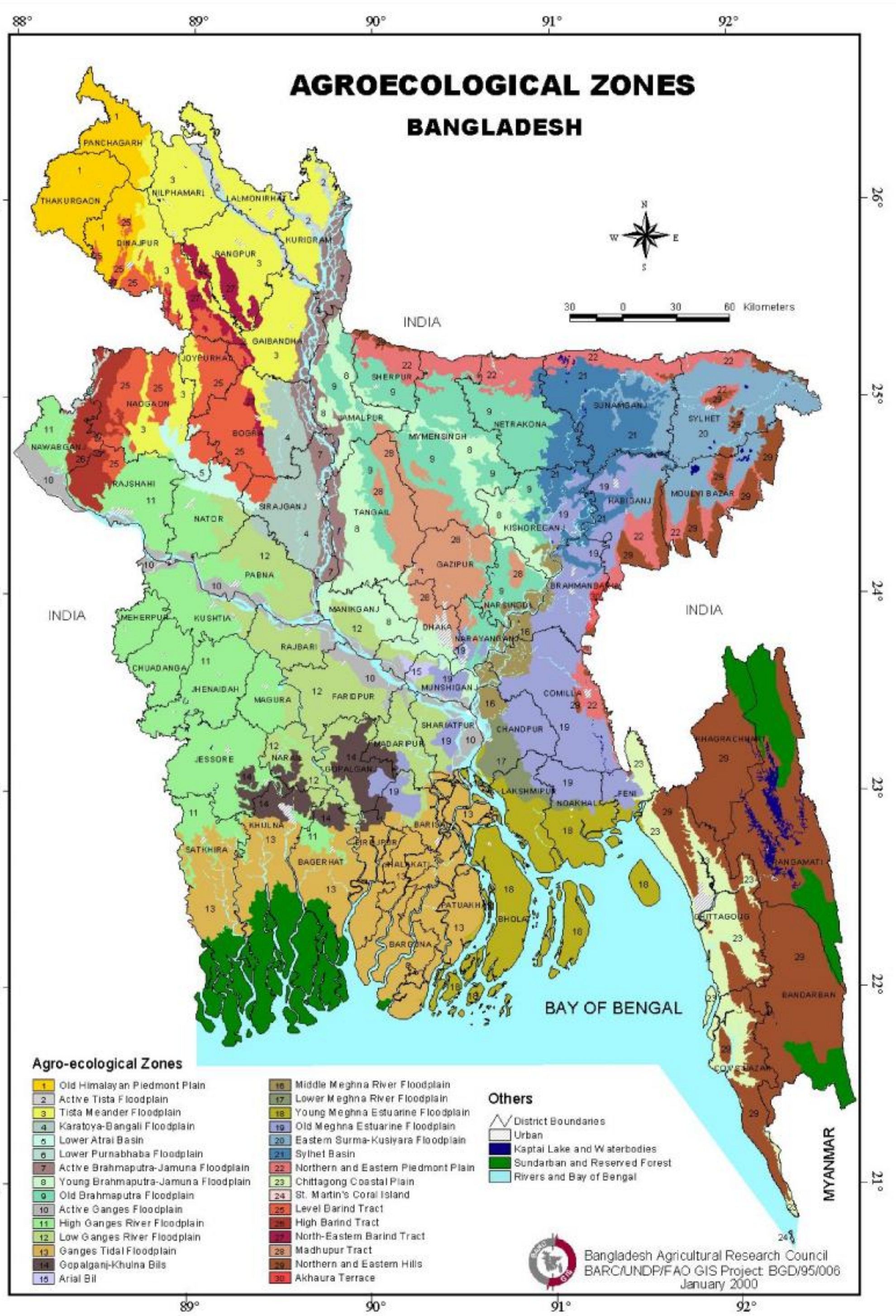
# CHAPTER VII
# APPENDICES

**Appendix I:** Monthly record of air temperature, rainfall and relative humidity of the experimental site during the period from February 2016 to June 2016

| Date/Week | Temperature ($^{o}C$) | | Relative humidity (%) | Rainfall (mm) (Total) |
|---|---|---|---|---|
| | Maximum | Minimum | | |
| February | 31 | 24 | 64 | 28.9 |
| March | 28 | 36 | 62 | 65.8 |
| April | 27 | 36 | 71 | 156.3 |
| May | 39 | 27 | 76 | 339.4 |
| June | 31 | 36 | 82 | 340.4 |

Source: Bangladesh Meteorological Department (Climate and Weather Division), Agargoan, Dhaka- 1207.

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




Source: Bangladesh Agricultural Research Council, Khamarbari, Dhaka.

**Appendix III. Cost incurred per hectare in different control measures applied against cucurbit fruit fly on bitter gourd during Kharif I, 2016 at SAU Dhaka**

[a] = Labor cost 500.00 Tk/day; [b] = Pheromone trap set 30.00 Tk/set; [c] = Lure 16 Tk/lure; [d] = Sevin (85 SP) 100 gm = 105 Tk.; [e] = Spinosad 20 ml = 205 Tk.; [f] =

| Treatment | Items of expenditure | Cost (Tk) |
|---|---|---|
| $T_1$=Pheromone trap(Cue-lure + soap; @ 4 days interval | Total no. of labors for giving treatment 1x500[a]<br>Pheromone trap set (for 3 replications) x 30[b]<br>Lure (for 3 replications) x 16[c]<br>Wheel powder<br>**Total cost** | 6000.00<br>180.00<br>96.00<br>120.00<br>**6396.00** |
| $T_2$=Poison bait trap(2 gm Sevin 85 WP + 100 gm Mashed Sweet Gourd + 10 ml Molasses; @ 4 days interval | Total no. of labors for giving treatment 1x500[a]<br>Earthen pot<br>Sweet gourd<br>Molasses<br>Sevin 85 SP (for 3 replications) x1[d]<br>**Total cost** | 6000.00<br>190.00<br>120.00<br>30.00<br>6.00<br>**6346.00** |
| $T_3$=Spinosad(0.08 ml per liter of water @ 7 days interval | Total no. of labors for spraying insecticide 1x500[a]<br>Spinosad (for 8 sprays) x 0.3[e]<br>**Total cost** | 4000.00<br>1111.00<br>**5111.00** |
| $T_4$=Bait spray (1L water + 10 ml Molasses + 1 ml Malathion @ 7 days interval), | Total no. of labors for spraying insecticide 1x500[a]<br>Malathion 57 EC (for 8 sprays) x 0.85[f]<br>Molasses<br>**Total cost** | 4000.00<br>755.56<br>1333.33<br>**6089.00** |
| $T_5$= $T_{1+}$ $T_2$ | Total no. of labors for giving treatment 1x500[a]<br>Pheromone trap set (for 3 replications) x 30[b]<br>Lure (for 3 replications) x 16[c]<br>Wheel powder<br>Earthen pot<br>Sweet gourd<br>Molasses<br>Sevin 85 SP (for 3 replications) x1[d]<br>**Total cost** | 6000.00<br>180.00<br>96.00<br>120.00<br>190.00<br>120.00<br>30.00<br>6.00<br>**6742.00** |
| $T_6$= $T_{1+}$ $T_3$ | Total no. of labors for giving treatment 1x500[a]<br>Pheromone trap set (for 3 replications) x 30[b]<br>Lure (for 3 replications) x 16[c]<br>Wheel powder<br>Spinosad (for 8 sprays) x 0.3[e]<br>**Total cost** | 4000.00<br>180.00<br>96.00<br>120.00<br>1111.00<br>**5507.00** |
| $T_7$= $T_{1+}$ $T_4$ | Total no. of labors for giving treatment 1x500[a]<br>Pheromone trap set (for 3 replications) x 30[b]<br>Lure (for 3 replications) x 16[c]<br>Wheel powder<br>Malathion 57 EC (for 8 sprays) x 0.85[f]<br>Molasses<br>**Total cost** | 4000.00<br>180.00<br>96.00<br>120.00<br>755.56<br>1333.33<br>**6485.00** |
| $T_8$=Neem oil (3 ml Neem Oil + 10 ml Trix + 1 L Water @ 7 days interval | Total no. of labors for spraying insecticide 1x500[a]<br>Neem oil<br>Trix<br>**Total cost** | 4000.00<br>444.44<br>1777.78<br>**6222.22** |
| $T_9$ (Untreated control) | No management cost at all | 00.00 |

Malathion (57 EC) 100 ml = 85 Tk.

# LIST OF ABBREVIATIONS AND ACRONYMS

| Abbreviation | Full meaning |
|---|---|
| BADC | Bangladesh Agriculture Development Corporation |
| BARI | Bangladesh Agricultural Research Institute |
| BBS | Bangladesh Bureau of Statistics |
| BCPC | British Crop Production Council |
| BCR | Benefit Cost Ratio |
| CV | Coefficient of variation |
| $^{o}C$ | Degree Celsius |
| DAT | Days After transplanting |
| d.f. | Degrees of freedom |
| *et al.* | And others |
| EC | Emulsifiable Concentrate |
| FAO | Food and Agriculture Organization |
| Fig. | Figure |
| G | Gram |
| Ha | Hectare |
| IPM CRSP | Integrated Pest Management Collaborative Research Support |
| J. | Journal |
| Kg | Kilogram |
| LSD | Least Significant Difference |
| Mg | Milli gram |
| Ml | Milli liter |
| MoP | Muriate of Potash |
| % | Percent |
| RCBD | Randomized Complete Block Design |
| SAU | Sher-e-Bangla Agricultural University |
| TSP | Triple Super Phosphate |
| WP | Wettable Powder |