EVALUATION OF DIFFERENT ECO-FRIENDLY MANAGEMENT PRACTICES AGAINST FRUIT FLY OF BOTTLE GOURD

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JUNE 2022

EVALUATION OF DIFFERENT ECO-FRIENDLY MANAGEMENT PRACTICES AGAINST FRUIT FLY OF BOTTLE GOURD

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REGISTRATION NO. 15-06733

A Thesis

Submitted to the Department of Entomology, Faculty of Agriculture,
Sher-e-Bangla Agricultural University, Dhaka
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE (MS)
IN
ENTOMOLOGY

SEMESTER: JANUARY-JUNE, 2022

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CERTIFICATE

*This is to certify that thesis entitled **"EVALUATION OF DIFFERENT ECO-FRIENDLY MANAGEMENT PRACTICES AGAINST FRUIT FLY OF BOTTLE 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 **SHARMIN AKTER, Registration no. 15-06733** 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: June 2022
Place: Dhaka, Bangladesh

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DEDICATED

TO

MY BELOVED

PARENTS

ACKNOWLEDGEMENT

All the praises due to the Almighty Allah, the cherisher and sustainer of the world. His blessings have enabled the author to complete her thesis leading to Master of Science in Entomology degree.

The author expresses her heartiest gratitude, sincere appreciation, indebtedness and deep sense of respect to her adorable teacher, venerable Supervisor ***Dr. Md. Razzab Ali****, Professor, Department of Entomology, Sher-e-Bangla Agricultural University for his planning, painstaking and scholastic guidance, support, extraordinary kind concern, everlasting encouragement, inestimable cooperation and intellectual encircling the till final preparation of the thesis.She expresses her profuse gratitude, cordial appreciation and gratefulness to her thoughtful, Co-supervisor* **Associate Prof. Md. Rashedul Islam,** *Department of Entomology, Sher-e-Bangla Agricultural University, for her valuable suggestions, guidance constant encouragement and inestimable during the study.*

With due regards, the autor thanks the Chairman, Department of Entomology, Sher-e-Bangla Agricultural University, for the facilities provided, in carrying out this work. She also acknowledges with deep regards to the help and cooperation received from her respected teachers and stuff of the Department of Entomology, Sher-e-Bangla Agricultural University while carrying out this work.

She expresses her heartiest gratitude sincere appreciation, indebtedness and deep sense of respect to her parents for their sincere and affectionate support and love, extraordinary kind concern, everlasting encouragement and inestimable cooperation during the entire period of study.

Dated: June, 2022 ***The Author***

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ABBREVIATIONS AND ACRONYMS

Abbreviation	Full meaning
AEZ	Agro-Ecological Zone
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
BMD	Bangladesh Meteorological Department
CV	Coefficient of Variation
^{o}C	Degree Celsius
et al.	And others
FAO	Food and Agriculture Organization
G	Gram
Ha	Hectare
IPM	Integrated Pest Management
J.	Journal
Kg	Kilogram
LSD	Least Significant Difference
Mg	Milligram
MoP	Muriate of Potash
%	Percent
SAU	Sher-e-Bangla Agricultural University
SRDI	Soil Resources Development Institute
TSP	Triple Super Phosphate

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EVALUATION OF DIFFERENT ECO-FRIENDLY MANAGEMENT PRACTICES AGAINST FRUIT FLY OF BOTTLE GOURD

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ABSTRACT

The study was conducted in the experimental field of Sher-e-Bangla Agricultural University , Dhaka during the period from October, 2021 to April, 2022 to find out the evaluation of different eco-friendly management practices against fruit fly of bottle gourd . The experiment was laid out in a Randomized Complete Block Design replicated with three replications. In this study, treatments T_1 = Using pheromone trap; T_2 = Using bait trap with banana mashed at 5 days interval; T_3 = Using bait trap with sweet gourd mashed at 5 days interval; T_4 = Using pheromone trap + Using bait trap with banana mashed at 5 days interval; T_5 = Using pheromone trap + Using bait trap with sweet gourd mashed at 5 days interval; and T_6 = Untreated control where nothing were applied. T_5 showed the best performance in terms of number of fruit fly (4.09 adult) captured, percent reduction of fruit infestation by number over control at early (84.50%), mid (77.68%) and late (76.57%) fruiting stages; percent reduction of fruit infestation by weight over control at early (75.43%), mid (72.05%) and late (64.17%) fruiting stages; fruit length (54.87cm), fruit girth (24.37cm), single fruit weight (2.59kg) and yield (71.37t/ha) . The overall study revealed that, the most significant performance was achieved from T_5 treatment (Using pheromone trap + Using bait trap with sweet gourd mashed at 5 days interval) which contributed to highest control of cucurbit fruit fly as well as the maximum increase of healthy fruit length, girth and the yield.

CHAPTER I

INTRODUCTION

Bottle gourd (*Lagenaria siceraria*), belongs to the family Cucurbitaceae grown worldwide in the tropical climate of Africa, Asia, America and Europe. Bottle gourd is the most widely grown and consumed in all over Bangladesh, preferred mainly for its various compounds such as vitamins, minerals, antioxidants as well as its anticancer properties (Umar *et al.* 2013). It is an important and popular vegetable in Bangladesh which is consumed throughout the year. In Bangladesh, bottle gourd is used as curry and its leaves and stems are also used as vegetables (Hasan *et al.* 2017). Bottle gourd is a moderate source of vitamin C (100 g of raw fruit provides 10 mg or about 17% of Recommended Dietary Allowances). In addition, the vegetable is also a moderate source of thiamin, niacin (vitamin B-3), pantothenic acid (vitamin B-5), pyridoxine (vitamin B-6) and minerals such as calcium, iron, zinc, potassium, manganese and magnesium (Akter 2014).

In Bangladesh, cucurbits occupy 66% of the land under vegetable production and contribute 11% of the total vegetable production (BBS 2010), however its productivity is decreased due to several insect pests that have been reported to cause considerable damage in different parts of the world. The vegetables are produced throughout the year in Bangladesh, however most of the vegetables are produced in winter (Anon 2001). Bottle gourd is primarily a winter vegetable but now-a-days it is available also in summer. They are grown in homestead for family consumption as well as in larger plots for commercial purpose (Umar *et al.* 2013). In Bangladesh, Bottle gourd productivity is lower than the other countries. However, low yield may be attributed to a number of reasons viz. unavailability of quality seeds of high yielding varieties, delayed sowing, fertilizer management, disease and insect infestation and improper or limited irrigation facilities. A major and common problem is the high incidence of insect pests and inappropriate management practices. Cucurbits are infested with various insect right from the primordial stages of the crop to harvest of the product (Muthsamy *et al.* 2017). The main pests of cucurbit crops are leaf eating caterpillar, fruit fly, leaf miner, whiteflies, hadda beetle, aphid, ash weevil and red pumkin beetle (Butani and Jotwai 1984). The fruit fly, *Bactrocera cucurbitae* (Coq.) (Diptera: Tephritidae) is one of the most serious pests of cucurbits in Bangladesh (Akhtaruzzaman *et al.* 1999 and 2000, Alam 1969). This pest is also known as melon fly and sometimes as a cucurbit fruit fly. The fruit fly attacks the ultimate economic part, i.e. fruits of the crop that alone can inflict yield loss in different cucurbitaceous vegetables ranging from 30-100% depending upon cucurbit species and the season (Dhillon *et al.* 2005). The female fly drums on the skins of young fruits by her ovipositor and sometimes on the young leaves or stems of the host plants and makes punctures for laying eggs (Chaudhary and Patel 2007). After hatching egg in the fruit, the larvae feed into pulpy tissue and make tunnels in the fruits and cause direct damage. They also damage the fruits indirectly by contaminating with excreta and accelerated rotting of fruits by a pathogenic infection (Dhillon *et al.* 2005). Infested fruits if not rotten, become deformed and hardly which make it unfit for consumption. In Bangladesh where the production of vegetables is much below the requirements, the damage due to cucurbit fruit flies is undesirable (Sohel *et al.* 2018). Although there are different methods of controlling the pest but the growers in Bangladesh frequently use chemical insecticides (Karim 1995). But most of the cases, it is not possible to control fruit fly because its larvae live in the internal portion of fruits. In spite of its internal feeding, the 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 (Islam 2013). Pheromone traps attract only male fruit flies but this could be used as indicators of the total population. Pheromones are also increasingly efficient at low population densities, they do not adversely affect natural enemies, and they can, therefore, bring about a long-term reduction in insect populations that cannot be accomplished with conventional insecticides (Toledo *et al.* 2010).

Considering the hazardous impacts of using high level chemical pesticides on non-target organisms as well as environment the study was undertaken to assess the efficacy of different traps, against fruit fly to adopt ecofriendly and sustainable pest management system in cucurbits so that farmer can get satisfactory yield as well as consumers and get non-toxic fresh bottle gourd. In view of the above facts, specific objectives of this research were as follows:

- To evaluate management practices against the fruit fly infesting bottle gourd.
- To find out the capturing efficiency of pheromone trap and bait traps in controlling fruit fly in bottle gourd; and
- To establish an environmentally safe control measure(s) of fruit fly in cucurbit crops.

CHAPTER II

REVIEW OF LITERATURE

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

2.1. Cucurbit fruit fly

The first report on melon fruit flies was published by Bezzi (1913) who listed 39 species from India. Nearly 250 species are of economic importance, and are distributed widely in temperate, sub-tropical, and tropical regions of the world. *Bactrocera cucurbitae* (Coquillett) is a major threat to cucurbits. Senior-White (1924) listed 87 species of Tephritidae in India. Amongst these, the genus, *Bactrocera* (*Dacus*) causes heavy damage to fruits and vegetables in Asia. Fruit flies are also serious pests in Pakistan, causing losses at the farm level, and with added losses to traders, retailers and exporters.

2.2. Taxonomic position

The taxonomic position of cucurbit fruit fly is given bellow:

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

2.3. Geographical distribution

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

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

2.4. Life cycle

The survival of adults may long for a year at room temperature if fed on fruit juices. In general, its life cycle lasts from 21 to 179 days. Development from egg to adult stage takes 13 days at 29°C in Solomon Islands (Hollingsworth *et al.* 1997). High temperature, long period of sunshine and plantation activity influences the *B. cucurbitae* abundance in the North-Eastern Taiwan. Bhatia and Mahto (1969) reported that the life cycle is completed in 36.3, 23.6, 11.2, and 12.5 days at 15, 20, 27.5 and 30°C, respectively. There are 8 to 10 generations in a year (Weems and Heppner 2001).

2.4.1. Mating and Oviposition

According to Shivay *et al.* (2007) fruit flies mated during the night between 18:30 pm - 01:30 am. Adults begin to mate 9-12 days after emergence (Rituraj 2011).

Yamagishi and Tsubaki (1990) observed that no sperms were transferred during the first 0.5 h of copulation. Sperm transfer increased to nearly 6400 until 4h, and thereafter, the number of sperms remained almost unchanged up to 8h of copulation. The pre-oviposition period of flies fed on cucumbers ranged between 11 to 12 days (Hollingsworth *et al.* 1997). Pre-oviposition and oviposition periods range between 10 to 16.3, and 5 to 15 days, respectively, and the females live longer (21.7 to 32.7 days) than the males (15.0 to 28.5 days).

Mating between the adult male and female cucurbit fruit flies generally takes place at about dusk and lasts for about an hour or more. Studies on fruit fly mating behaviour revealed that most of flies in tropical and subtropical areas mate when light intensity decreases at dusk. Although some species belonging the genus *Bactrocera* prefer to mate in the morning and early afternoon (Allwood 2001). The mean Pre-oviposition period 13.5±1.5 and oviposition period 18.0 ± 6 days while, mean mating period (3±1 hrs), fecundity 80.0± 20 eggs/life cycle and incubation period of eggs varied from 1.25±0.25 days was observed of cucurbit fruit fly (Sohrab *et al.* 2018). Mir *et al.* (2014) and Lanjar *et al.* (2013) were fairly closed this experiment and who reported the respective range of preoviposition and oviposition (11 ± 0.62 and 19.29 ± 1.19) and 10-15 and 12-28 days respectively.

2.4.2. Incubation period

The eggs hatch within 18 hours in summer and 3–4 days in winter. The egg incubation period on pumpkin, bitter gourd, and squash gourd has been reported to be 4.0 to 4.2 days at 27 ± 1°C, 1.1 to 1.8 days on bitter gourd, cucumber and sponge gourd, and 1.0 to 5.1 days on bitter gourd (Hollingsworth *et al.* 1997). Hatching percent eggs of fruit fly 87.5 ± 2.5 was observed in 2015 at average maximum and minimum temperature 34.36–25.46°C and average relative humidity 87.5% respectively during experiment in the month of June and July (Sohrab *et al.* 2018).

Lanjar *et al.* (2013) were fairly close this experiment and who reported the respective range of incubation period of eggs of fruit fly were 1.4 ± 0.16 and 2.29 ± 0.18 days (30.32 ± 2.9^0 C) respectively. The eggs were hatch out from eggs in 1-1.5 days feed on the pulp and seeds of fruit, drop to the ground (Sohrab *et al.* 2018).

2.4.3. Larval period

Fully developed maggot of fruit fly was white in color white grey color patches on body. The apodous maggot was passed through 3 instars. Mean of total maggot period was with a mean 5.18 ± 1.16 days (Sohrab *et al.* 2018).Mir *et al.* (2014) and Lanjar *et al.* (2013) were fairly close this experiment and who reported the respective range of Maggots (larvae) period of cucurbit fruit fly were 5.9 ± 0.9, 12.25, 4.5-7.5, 7.00, 4-7, 8.94 ± 0.6, 4.5 ± 1.13 days (30.32 ± 2.9^0 C) respectively.

The description of different stages of maggots is as follow:

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

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

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

2.4.4. Pupal period

Pre-pupal period and pupal period was 0.75 ± 0.25 and 9.5 ± 0.5 days respectively during experiment in the month of June and July (Sohrab *et al.* 2018). The duration of pupal stage varied 9 to 10 days with a mean of 9.5 ± 0.5 days, respectively. Mir *et al.* (2014) and Lanjar *et al.* (2013) were fairly close and differ this experiment result and who reported the respective range of pupal period of cucurbit fruit fly were 7.3 ± 0.23, 7.75, 7.00-711.50, 8.33, 9, 9.94 ± 1.03 and 8.4 ± 0.51 days respectively at different hosts, time, weather conditions and etc.

2.4.5. Adult longevity

The average longevity of adult fruit flies were neither food nor water immediately, die after range of 1.5 ± 0.5 days after emergence from pupa. When cucurbit vegetables materials were provided to fruit flies then fruit flies were lived 13.5 ± 1.5 days. The duration of total life cycle was 16.81 ± 2.18 days during 2015 in June and July under room temperature in meerut condition (Sohrab *et al.* 2018). Mir *et al.* (2014) and Lanjar *et al.* (2013)were fairly closed and differed this experiment and who reported the respective range of adult longevity of cucurbit fruit fly were 13.09 ± 2.7, 18.4 ± 0.64, 26.00, 37.86 ± 1.40 and 30-52 days respectively at different hosts, time, temperature and weather conditions.

2.4.6. Total life cycle

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. High temperature, long period of sunshine and plantation activates influence the *B. cucurbitae* abundance in the Northeastern Taiwan. Development from egg to adult stage takes 13 days at 29°C in Solomon Islands. There are 8 to 10 generations in a year (Weems and Heppner 2001).

2.4.7. Fecundity

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

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

2.5. Host preference

Primary hosts are species of Cucurbita, as follows: *Cucumis melo*, *Cucurbita maxima, Cucurbitapepo* and *Trichosanthescucumerina* (Allwood *et al.* 2001).

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

Benincasa hispida, fruit and flowers, *Citrullus colocynthis*, *Citrullus lanatus*, *Coccinia grandis,* fruit and flowers*, Cucumis anguria*, *Cucumis sativus*, *Cucurbita moschata,* fruit and flowers, *Lagenaria siceraria*, *Luffa acutangula*, *Luffa aegyptiaca*, fruit and flowers, *Momordica balsamina*, *Momordica charantia*, *Momordica* *cochinchinensis* and *Momordica dioica*, *Carica papaya*,*Phaseolus vulgaris*, *Vigna sinensis* and *Vigna unguiculata*, *Strychnos nux-vomica*,*Abelmoschus moschatus*,*Psidium guajava*,*Pandanuso doratissi* [*Pandanusodorifer*],*Passifloraedulis*,*Ziziphusjujuba*,*Manilkarazapota* and *Lycopersiconesculentum* (Allwood *et al.* 2001).

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

Cucumis trigonus, *Diplocyclos palmatus*, *Gymnopetalum integrifolium*, *Melothria wallichii*, *Mukia maderaspatana* [*Cucumis maderaspatanus*], *Trichosanthes ovigera, Trichosanthes tricuspidata, Trichosanthes wallichiana* and *Trichosanthes wawraei*,*Dracaena curtissi*,*Capparis sepiaria*, *Capparis thorellii* and *Maeruasiamensis*,*Ficuschartacea*,*Citrushystrix*,*Solanumtrilobatum*,*Tetrastigmalance olarium* (Allwood *et al.* 2001).

2.6. Damage assessment

Females lay their eggs mostly on soft fruit tissue (fruit in formation) and produce necrotic areas (brown dots) over the surface of the fruit and as a result the marketability of the product is reduced. Immature feed inside the fruits (although sometimes they can move to feed in other plant structures such as flowers or the stems), bore into the pulp tissue and make their feeding galleries, as a result fruits rot or becomes distorted. Normally, early instar larvae leave the necrotic areas of the fruit and move to healthy tissue expanding the damage and at the same time introducing various pathogens and hastening fruit decomposition (Dhillon *et al.* 2005a).It prefers young, green, and tender fruits for egg laying. The females lay the eggs 2 to 4 mm deep in the fruit pulp, and the maggots feed inside the developing fruits. At times, the eggs are also laid in the corolla of the flower, and the maggots feed on the flowers. A few maggots have also been observed to feed on the stems. The fruits attacked in early stages fail to develop properly, and drop or rot on the plant. Since, the maggots damage the fruits internally, it is difficult to control this pest with insecticides. Therefore, there is a need to explore alternative methods of control, and develop an integrated control strategy for effective management of this pest. The available information on the melon fruit fly has been reviewed in this manuscript to explore the possibilities for successful management of this pest in cucurbits.

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

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

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

Maggots feed inside the fruits, but at times, also feed on flowers, and stems. Generally, the females prefer to lay the eggs in soft tender fruit tissues by piercing them with the ovipositor. A watery fluid oozes from the puncture, which becomes slightly concave with seepage of fluid, and transforms into a brown resinous deposit.

Sometimes pseudo-punctures (punctures without eggs) have also been observed on the fruit skin. This reduces the market value of the produce. In Hawaii, pumpkin and squash are heavily damaged even before fruit set. The eggs are laid into unopened flowers, and the larvae successfully develop in the taproots, stems, and leaf stalks. <1% damage by pseudo-punctures by the sterile females in cucumber, sponge gourd and bitter gourd. After egg hatching, the maggots bore into the pulp tissue and make the feeding galleries. The fruit subsequently rots or becomes distorted. Young larvae leave the necrotic region and move to healthy tissue, where they often introduce various pathogens and hasten fruit decomposition. The vinegar fly, *Drosophilla melanogaster* has also been observed to lay eggs on the fruits infested by melon fly, and acts as a scavenger (Dhillon *et al.* 2005b). The extent of losses vary between 30 to 100%, depending on the cucurbit species and the season. Fruit infestation by melon fruit fly in bitter gourd has been reported to vary from 41 to 89%. The melon fruit fly has been reported to infest 95% of bitter gourd fruits in Papua (New Guinea), and 90% snake gourd and 60 to 87% pumpkin fruits in Solomon Islands (Hollingsworth *et al.* 1997). Singh *et al.* (2000) reported 31.27% damage on bitter gourd and 28.55% on watermelon in India.

2.7. Management practices against cucurbit fruit fly

Cucurbit fruit fly is the major pest causes considerable economic damage of bottle gourd. It is important to manage or control the pest before its outbreak. Different types of attractants, cucurbit fruit fly traps (Nasiruddin and Karim 1992) and repellants of plant extracts were utilized against this pest with variable success.

2.7.1. Resistant cultivars against cucurbit fruit fly

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

2.7.2. Management with male-sterile technique

Sterile males are released in the fields for mating with the wild females. Sterilization is accomplished through irradiation, chemo-sterilization, or by genetic manipulation. In sterile insect programs the terms 'sterility' or sterile insect' refer to the transmission of dominant lethal mutations that kill the progeny. The females either do not lay eggs or lay sterile eggs. Ultimately, the pest population can be eradicated by maintaining a barrier of sterile flies. A sterile insect program is species specific, and is considered an ecologically safe procedure and has been successfully used in area-wide approaches to suppress or eradicate pest insects in entire regions such as the pink bollworm, *Pectinophora gossypiella* in California, the tsetse fly, *Glossina austeni* in Zanzibar, the New World screwworm, *Cochliomyia hominivorax* in North and Central America, and various tephritid fruit fly species in different parts of several continents (Klassen *et al.* 1994). In the Mediterranean fruit fly (medfly), *Ceratitis capitata*, release of sterile males increased the effectiveness of the sterile insect program (Hendrichs *et al.* 2005). However, the suppression of *B. cucurbitae* reproduction through male annihilation with cuelure may be problematic. Although, the sterile insect technique can be used successfully to suppress economically important pest species, conventional sterilization by ionizing radiation reduces insect fitness, which can result in reduced competition of the sterilized insects (Horn and Wimmer 2003). A transgene-based, female-specific expression method of a conditional dominant lethal gene (Horn *et al.* 2002, Atkinson *et al.* 2001; Handler 2001), has been well tested in *Drosophila melanogaster* and might be transferable to other insect pest species (Horn and Wimmer 2003, Heinrich and Scott 2000, Thomas *et al.* 2000). Thus, the transgene based, dominant embryo lethality system can generate large numbers of competitive and vigorous sterile males, and can be used successfully in a sterile insect program.

2.7.3. Management with pheromone trap

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). According to Vargas *et al.* (2000) methyl eugenol and cuelure were highly attractive kairomone lures to oriental fruit fly, *B. dorsalis* and melon fly, *B. cucurbitae*, respectively. Yubak Dhoj (2001) reported that Fruit fly (*Bactrocera cucurbitae* Coquilet. Diptera: Tephritidae) is considered as 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 cuelure 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.

Singh *et al.* (2007) tested sex attractant methyl eugenol, cuelure and food attractant protein hydrolysate for attraction to fruit flies and reported that five fliy species *viz.*, *B. zonata, B. affinis* (Hardy), *B. dorsalis, B. correcta and B. diversa* (Coquillett) were attracted to methyl eugenol traps and two species *viz*., *B. cucurbitae* and *B. nigrotibialis* (Perkins) to cuelure traps and two species namely, *B. cucurbitae* and *B. zonata* to protein hydrolysate traps. Vargas *et al.*(2009) evaluated various traps with methyl eugenol and cuelure for capturing fruit flies and observed that *B. dorsalis* was captured in methyl eugenol traps and *B. cucurbitae* in cuelure traps. Rakshit *et al.* (2011) assessed the economic benefits of managing fruit flies infecting sweet gourd using pheromones. In this study, a pheromone called Cuelure imported by the Bangladesh Agricultural Research Council (BARC) was used for suppressing fruit fly infesting sweet gourd. Analysis of the potential benefits of farmers adopting the Cuelure technology projects that benefits over 15 years range from 187 million Taka or $2.7 million to 428 million Taka or $6.3 million, depending on assumptions. The projected rate of return on the BARI investment in pheromone research ranges from 140 to 165 percent. The size of these returns implies that pheromone research at BARI has a high economic return and that Bangladesh benefits significantly as Cuelure becomes more widely available to farmers. 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), cuelure (C-L) (4-(p-acetoxyphenyl)-2-butanone), and raspberry ketone (RK) (4-(p-hydroxyphenyl)-2-butanone) are powerful male-specific lures. Most evidence suggests a role of ME and C-L/RK in pheromone synthesis and mate attraction. ME and C-L/RK are used in current fruit fly programs for detection, monitoring, and control. During the Hawaii Area-Wide Pest Management Program in the interest of worker safety and convenience, liquid C-L/ME and insecticide (i.e., naled and malathion) mixtures were replaced with solid lures and insecticides.

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

The genus *Bactrocera* consists of over 500 species distributed in the tropical and subtropical regions of Asia (Smith *et al.* 2003) and includes many serious and/or highly invasive polyphagus pest species, namely *B. correcta* (Bezzi)–guava fruit fly, *B. cucurbitae* (Coquillett)–melon fly, *B. carambolae* (Drew & Hancock)–carambola fruit fly, *B. dorsalis* (Hendel)–oriental fruit fly, *B. papayae* (Drew & Hancock)–Asian papaya fruit fly, *B. philippinensis* (Drew & Hancock)–Philippines fruit fly, *B. latifrons* (Hendel)–solanaeous fruit fly, *B. tryoni* (Froggatt)–Queensland fruit fly, *B. umbrosa* (Fabricius)–Artocarpus or jack-fruit fly and *B. zonata* (Saunders)–peach fruit fly. Males of these species, with the exception of *B. cucurbitae* and *B. tryoni* (both attracted to cue-lure (CL)/raspberry ketone (RK)) and *B. latifrons* (not attracted to either CL/RK or methyl eugenol (ME), are attracted to ME, a compound found in a wide diversity of plant species (Tan and Nishida 2012) and now known to be a pheromonal precursor. As discussed below, the strong attraction of males to ME has, to some degree, limited impetus to explore sex pheromones as a trapping tool for *Bactrocera s*pecies. Here, we summarize the chemistry of *Bactrocera* pheromones and note studies that have monitored male or female attraction to pheromonal emissions. *B. papayae* males visiting an orchid whose floral fragrance contained zingerone (a compound structurally similar to ME) were found to have zingerol in the rectal gland, suggesting a role in pheromone synthesis for this compound as well (Tan and Nishida 2000). More recently, Tan *et al.* (2011, 2013) found ECF and DMP in the rectal sac of ME-fed males of *B. invadens* and *B. philippinensis*. Males of *B. carambolae* differ from the aforementioned species in that they produce only ECF after ingesting ME (Wee and Tan 2005a, Tan and Nishida 1996).

Since Nishida *et al.* (1996) reporting, a number of studies have demonstrated that ME consumption increases male mating success in several species in the *B. dorsalis* complex (Obra and Resilva 2013; Orankanok *et al.* 2013; Shelly 2010a; Wee *et al.* 2007; Tan and Nishida 1996, 1998; Shelly *et al.* 1996; Shelly and Dewire 1994). However, the role of pheromone composition in determining this outcome is not known with certainty. Analogous to the *B. dorsalis* complex, ingestion of CL/RK has been shown to enhance male mating success, though the effect appears short-lasting both for *B. cucurbitae* (1 day after feeding, Shelly 2000b, Shelly and Villalobos 1995) and *B. tryoni* (1–3 days after feeding, Kumaran *et al.* 2013). *B. tryoni* males fed zingerone were also found to have a mating advantage over control males deprived this compound (Kumaran *et al.* 2013). The role of the sex pheromone in influencing male mating success is unknown. Kobayashi *et al.* (1978) found that *B. cucurbitae* females were attracted to male rectal glands as well as live males (in neither case were males fed CL/RK) but that the attraction was far weaker than that observed for *B. dorsalis* females to conspecific males. In wind tunnel trials, Khoo and Tan (2000) demonstrated that CL-fed and zingerone-fed males of *B. cucurbitae* attracted more females compared to males deprived these compounds, which strongly suggests a sex pheromonal role for these exogenous phenyl butanoids. To our knowledge, there are no laboratory or field data available investigating the effect of the male sex pheromone on female attraction or male mating success in *B. tryoni*.

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

2.12.4. Management with poison bait trap

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

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

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).

2.7.5. Management with neem oil

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.

2.7.6. Management with biological control agent

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

G. virens affected the oviposition and development of *B. cucurbitae* adversely (Sinha and Saxena 1999).

2.7.7. Management with chemical control

The application of molasses+malathion (Limithion 50EC) and water in the ratio of 1:0.1:100 provides good control of melon fly (Akhtaruzzaman *et al.* 2000). Application of either 0.05% fenthion or 0.1% carbaryl at 50% appearance of male flowers, and again at 3 days after fertilization is helpful in reducing the melon fly damage (Srinivasan 1991).

Reddy (1997) reported triazophos to be the most effective insecticide against this pest on bitter gourd. Highest yield and lowest damage were observed in pumpkin when treated with carbofuran at 1.5 kg a.i./ha at 15 days after germination (Borah 1998). An extract of Acorus calamus (0.15%) reduced the adult longevity from 119.2 days to 26.6 days when fed continuously with sugar mixed with extract (at 1ml/g sugar) (Nair and Thomas 1999). Neem oil (1.2%) and neem cake (4.0%) have also been reported to be as effective as dichlorvos (0.2%) (Ranganath *et al.* 1997).

2.7.8. Management with cultural practices

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

Akhtaruzzaman *et al.* (1999) suggested cucumber fruits should be bagged at 3 days after anthesis, and the bags should be retained for 5 days for effective control. It is an environmentally safe method for the management of this pest. The most effective method in melon fruit fly management uses primary component- field sanitation. To break the reproduction cycle and population increase, growers need to remove all un-harvested fruits or vegetables from a field by completely burying them deep into the soil. Burying damaged fruits 0.46 m deep in the soil prevents adult fly eclosion and reduces population increase (Klungness *et al.* 2005).

2.7.9. IPM packages against cucurbit fruit fly

Fruit fly IPM systems range from programs for individual homeowners and farmers to large areas of many square kilometers. During the twenty first century the Regional Fruit Fly Project in the Pacific pioneered the implementation of sustainable technologies throughout many Pacific Island Countries for control of *Bactrocera* fruit flies (Allwood *et al.* 2015, Allwood *et al.* 2001). These technologies included fipronil-based bait sprays and male annihilation treatments, in conjunction with cultural controls. Similarly, the HAWPM program tested and demonstrated larger IPM programs to control *B. dorsalis* and *B. cucurbitae* that included: (1) field sanitation, (2) protein bait, (3) lures, (4) SIT and (5) biological control (Vargas *et al.* 2008). This program registered many technologies for farmers and homeowners and promoted the use of safer or reduced risk fruit fly protein baits and MAT traps in what became popularly referred to as the "1 (sanitation), 2 (protein bait), 3 (male lure trapping) approach" for fruit fly control (Mau *et al.* 2009). For example, in a study that aimed at assessing the efficacy of GF-120 NF Naturalyte Fruit Fly Bait sprays in conjunction with field sanitation to control *B. dorsalis* in papaya orchards in Hawaii, Piñero *et al.* (2009) reported significant reductions in numbers of female *B. dorsalis* captured by monitoring traps and in levels of infestation of papaya fruit by *B. dorsalis* only when both GF-120 was applied in a sustained manner in conjunction with field sanitation and male annihilation.Verghese *et al.* (2004) evaluated the effectiveness of an IPM package targeting *B. dorsalis* in mango orchards in India with good results, integrating MAT, field sanitation and insecticide sprays. Best results were obtained when MAT, sanitation and delta-methrin were combined with azadirachtin over a two-year period. In a study conducted in mango orchards in India, Singh *et al.* (2013) reported that *B. dorsalis* and *B. zonata* (Saunders) were effectively suppressed by integrating multiple approaches. Maximum fruit protection (94.5%) was recorded with integration of MAT+sanitation+soil drenching with 0.1% chorpyriphos+bait cover spray (0.05% malathion+0.2% Protinex). This was followed by a combination of MAT+sanitation+soil drenching (87.3% protection), MAT+sanitation+cover spray (81.8% protection) and MAT+sanitation (65.5% protection). Clearly, the removal of soil drenching or bait cover sprays reduced the effectiveness of the crop protection program, highlighting the need to include chemical controls into suppression programs of aggressive species, such as *B. dorsalis*. Gogi *et al.* (2014) reported a reduction in infestation of *Momordica charantia* L. by *B. cucurbitae*, leading to increased marketable yields through the integration of three components of cultural management: (1) Early sowing, (2) Hand Sowing Method (HSM), and (3) Sanitation.

Although *B. oleae* is more of a sub-tropical than a tropical pest species, methods to manage it have been similar to tropical species. Integrated control of *B. oleae* was proposed soon after the pest was found in the olive production areas of California (Collier and Van Steenwyk 2003). Recommendations for commercial orchards included releases of biological control parasitoids (*Psyttalia humilis* (Silvestri), *P. concolor* (Szépligeti), and *P. lounsburyi* (Silvestri)), cultural controls, attract-and-kill traps and GF-120 NF Naturalyte Fruit Fly Bait. Sanitation has been a major consideration, accomplished by removing all unharvested fruits and standing water in orchards that provide adults with water (Yokoyama 2015). Attract-and-kill traps (Johnson *et al.* 2006) used as bait stations have shown promise for *B. oleae* control and greatly reduce the amount of bait spray applied in olive orchards because they attract the pest to an attractive device that contains the toxicant (Yokoyama 2014, Yokoyama 2014). Most challenging have been the accidental introductions of fruit flies into the US mainland. Recently STATICTM Spinosad-ME, developed late in the HAWPM program, has been registered in California and Florida for use with GF-120 against accidental introductions of *Bactrocera*. In addition, lambda-cyhalothrin has been tentatively approved as a replacement for diazinon for use as a soil drench in Florida. Research continues on the possible use of Entrust SG as a biopesticidal soil drench as part of a three-pronged area-wide IPM system for control of fruit flies accidentally introduced into the U.S. mainland (Stark *et al.* 2014). The primary technology used is the release of millions of sterile *C. capitata* flies in California and Florida. When infestations are found, the program is supplemented with fruit stripping and treatment of host trees with GF-120. This same SIT approach could also be used for suppression of many *Bactrocera* fruit flies (e.g., *B. dorsalis* and *B. cucurbitae*) if it was not for the effectiveness of MAT (Vargas *et al.*2015).

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

The combined use of pheromone and MSG bait catches more flies and keep lower the fruit infestation and higher economic returns in cucumber (Nasiruddin *et al.* 2004). The combined use of pheromone traps baited with 'cuelure' along with MSG bait trap captured 2.3 times higher number of fruit flies than that caught in MSG bait traps alone. Three times less infestation and 2.8 times more yield were recorded at Kashimpur during winter 2001 from the sweet fields having joint treatment of pheromone and MSG traps (Nasiruddin *et al.* 2004).Baiting with culelure+MSG has the greatest advantage in fruit fly control in bitter gourd field (Rajotte 2003).

The recent wide area management program eradication program of *B. cucurbitae* in Seychelles demonstrated a three tier model including a) initial population reduction using bait sprays, b) elimination of reproduction using parapheromone lure blocks to eradicate males and thus prevent oviposition by females, and c) intensive surveying by traps and fruit inspection, until it can be certain that the pest is entirely eradicated (Mumford 2004). An IPM program that used field sanitation, protein bait applications, male annihilation, and release of sterile flies and parasites reduced fruit fly infestation from 30 to 40% to less than 5%, and cut organophosphate pesticide use by 75 to 90% (Vargas 2004). The USDA-ARS areawide IPM programs of melon fruit fly started in 1999 in collaboration with the Hawaiian State Department of Agriculture and University of Hawaii, using the environmentally sound strategies such as field sanitation, male annihilation with male lures and attractants, protein bait sprays/traps, augmentative releases of biological control agents (*Fopius arisanus* and *Psyttalia fletcheri*), and sterile insect release. It has proved to be economically viable, environmentally sensitive, sustainable, and has suppressed fruit flies below economic thresholds with the minimum use of organophosphate and carbamate insecticides (Klungness *et al.* 2005; Vargas *et al.* 2003; Mau *et al.* 2003b; Wood 2001).

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

CHAPTER III

MATERIALS OF METHODS

The experiment on the effect of evaluation of different eco-friendly management practices against fruit fly of bottle gourd was carried out at the experiment field of the Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh during October, 2021 to April, 2022. The materials and methods adopted in this study are discussed in the following sub headings:

3.1. Experimental site

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

3.2. Soil

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

3.3. Climate

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

3.4. Planting material

The variety BARI Lau 4 of Bottle gourd was selected for the experiment during Rabi season 20201-2022. The seed was collected from Bangladesh Agricultural Research Institute, Joydebpur, Gazipur.

3.5. Experimental design and layout

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications in the central farm of SAU. The field with good tilth was divided into 3 blocks. Each block was sub-divided into 6 sub plots, each of which was of 3.5 m × 2.5 m maintaining plot to plot distance 1.0 m and row to row distance 0.5m.

3.6. Land preparation

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

3.7. Fertilizer application : Urea, Triple Super Phosphate (TSP) and Muriate of Potash (MoP) were used as a source of nitrogen, phosphorous, and potassium, respectively. Manures and fertilizers that were applied to the experimental plot are presented in Table 1.

Table 1: Dose of application of fertilizers in sweet gourd field

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

The total amount of cowdung, TSP and MoP was applied as basal dose at the time of land preparation. Urea was applied at four installments as 1st, 2nd, 3rd and 4thharvest respectively.

Plate 1. Application of 2nd dose of urea fertilizer

3.8. Seeds sowing, seedling raising and transplanting

Collecting seeds of BARI Lau 4 of Bottle gourd were soaked for 12 hours in water for rapid and uniform germination. Then seeds were sown in the polyethylene bags (12cm x 18cm) containing a mixture of equal proportion of well decomposed cowdung and loam soil in 3 October 2021 and irrigated regularly. After germination, the seedlings were sprayed with water by hand sprayer and sprayed was done once a day for two weeks. Seedlings were placed in a shady place.

Plate 2. Raising Seedling

After 24 days of sowing, Seedlings were transplanted on 27th October, 2021 in the pits of the experimental field (two seedlings per pit and 2 pits per plot). At the time of transplanting, polyethylene bags was cut and removed carefully in order to keep the soil intact with root of the seedling. Finally one healthy plant was kept in each pit and damaged seedlings were replaced by new one.

3.9. Cultural practices

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

Plate 3. Red pumpkin beetle infestation in bottle gourd

3.10. Treatments of the experiment

T_1 = Using Pheromone trap

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

T_3 = Using Bait trap with sweet gourd mashed at the 5 days interval

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

T_5 = Using Pheromone trap + Using Bait trap with sweet gourd mashed at the 5 days interval

T_6 = Untreated control

3.11. Collection of trap and trap materials

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

3.12. Preparation of the different traps use as treatments

The pheromone, ‘cuelure’, which mimics the scent of female flies, attracts the male flies and traps them in large numbers resulting in mating disruption (Wong *et al.* 1991).

3.12.1. Sex pheromone trap

Pheromone trap was collected from Ispahani Agro-Biotec Ltd. Konabari, Gazipur and set in the experimental field. Sex pheromone traps designed by BARI with cuelure and soapy water, were used to conduct this experiment. The traps were hung up under bamboo scaffold, 60 cm above the ground. The soap water was replaced by new soap water at an interval of 5 days each.

Plate 4. Installation of pheromone trap in the experimental field

3.12.2. Bait trap with Banana mashed

This poison bait was prepared from mashed banana mixed with water and Sevin 50WP at the rate of 2 g per 100 g of mashed banana. Freshly prepared baits in earthen pots were placed at 50 cm above the ground with the help of bamboo supports. An earthen cover plate was placed 20 cm above the bait container to protect the bait material from sun and rain. Used baits were changed by freshly prepared baits within 5 days to attract more fruit flies.

Plate 5. Capture of fruit fly in Banana bait trap.

3.12.3. Bait trap with sweet gourd mashed

The poison bait trap was prepared using mashed sweet gourd mixed with water and Sevin 50WP at the rate of 2 g per 100 g of mashed sweet gourd. The bait was kept in a small earthen pot placed within a four splitted bamboo sticks, 50 cm above the ground. An earthen cover plate was placed 20 cm above the bait container to protect the bait material from sun and rain. The number of adult fruit flies (male and female) trapped in those bait traps were recorded at each 5 days interval in the morning. The old bait materials were changed at the interval of 5 days each and fresh ones were placed there for further use.

Plate 6. Capture of fruit fly in sweet gourd bait trap.

3.13. Data collection

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

3.13.1. Number of adults captured at different days interval

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

3.13.2. Percent fruit infestation by number

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

% Fruit infestation by number $= \frac{Number\ of\ infested\ fruits}{Total\ number\ of\ fruits}$ X 100

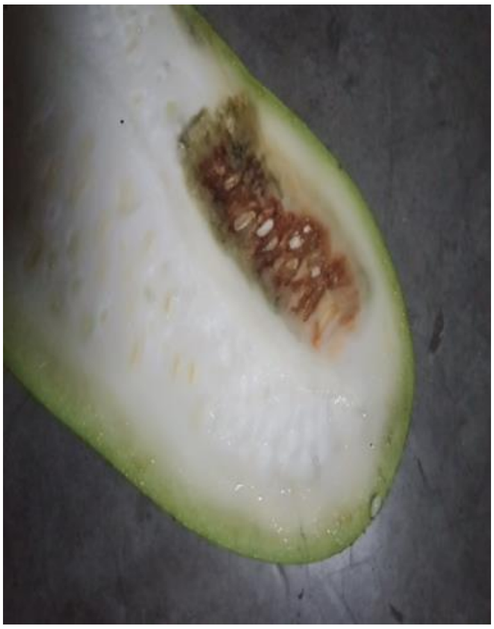

Plate 7. Fruit infestation by fruit fly

Plate 8. Infestation of bottle gourd at early stage

3.13.3. Fruit yield

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

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

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

3.13.4. Weight of infested fruits: For the estimation of weight of infested fruits per plot, fruits were randomly selected and weight was recorded from each plot, at each time of data collection.

Plate 9. Weight of bottle gourd

3.13.5. Length of healthy and infested fruits: For the estimation of length of 10 randomly selected healthy and infested fruits per plot, fruits were randomly selected and length was recorded, from each plot, at each time of data collection.

3.13.6. Girth of healthy and infested fruits: For the estimation of girth of 10 randomly selected healthy and infested fruits per plot, fruits were randomly selected and girth was recorded, from each plot, at each time of data collection.

3.14. Statistical analysis

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

CHAPTER IV

RESULTS AND DISCUSSION

The research work was consisted the experiment on the study of evaluation of different eco-friendly management practices against fruit fly of bottle gourd during the period from October, 2021 to April, 2022. The results have been presented and discussed in details under the following headings and sub-headings:

4.1. Number of captured insects per trap at different stages of bottle gourd

The number of captured insects per trap at different fruiting stages of bottle gourd after trap setting are represented in Table 2. From the Table 2. it was found that, among the different treatments T_5 (Pheromone trap + Bait trap with sweet gourd mashed) showed the best performance in capturing adult cucurbit fruit fly at different fruiting stages of bottle gourd. At early fruiting stage, the highest number of fruit fly (6.33 adults) was captured in T_5 (Pheromone trap + Bait trap with sweet gourd mashed) treatment, which was significantly different from the all other treatments and followed by 5.76 and 4.21 in T_4 (Pheromone trap + Bait trap with banana mashed) and T_1 (Pheromone trap), respectively; whereas the lowest number of fruit fly (3.33 adults) was captured in T_2 (Bait trap with banana mashed) which was closely followed by 3.88 in T_3 (Bait trap with sweet gourd mashed) treatment. More or less similar trend was observed in mid and late fruiting stages of bottle gourd.

In case of average number of adult cucurbit fruit fly captured per trap, the highest number of fruit fly (4.09 adults) was captured in T_5 (Pheromone trap + Bait trap with sweet gourd mashed) treatment, which was significantly different from the all others treatment and followed by 3.41 and 2.75 in T_4 (Pheromone trap + Bait trap with banana mashed) and T_1 (Pheromone trap), respectively; whereas the lowest number of fruit fly (1.88 adults) was captured in T_2 (Bait trap with banana mashed) which was closely followed by 2.38 in T_3 (Bait trap with sweet gourd mashed) treatment.

Table 2. Number of captured insects per trap at different fruiting stages of bottle gourd

Treatments	Number of captured insects/trap at different stages of fruiting			
	Early fruiting stage	Mid fruiting stage	Late fruit stage	Average
T_1	4.21 c	2.67 b	1.37 b	2.75 c
T_2	3.33 e	1.65 d	0.67 c	1.88 e
T_3	3.88 d	2.23 c	1.03 c	2.38 d
T_4	5.76 b	2.81 b	1.66 b	3.41 b
T_5	6.33 a	3.47 a	2.47 a	4.09 a
T_6	-	-	-	-
CV(%)	5.76	8.39	7.37	5.33
$LSD_{(0.05)}$	0.63	0.56	0.68	0.43

[In a column, numeric value represents the mean of 3 replications; each replication is derived from plot per treatment; in a column means having similar letter(s) are statistically identical at 0.05 level of probability.

Here, T_1 = Using Pheromone trap; T_2 = Using Bait trap with Banana mashed at the 5 days interval; T_3 = Using Bait trap with sweet gourd mashed at the 5 days interval; T_4 = Using Pheromone trap + Using Bait trap with Banana mashed at the 5 days interval; T_5 = Using Pheromone trap + Using Bait trap with sweet gourd mashed at the 5 days interval; T_6 = Untreated control]

As a result, the trend of captured adult cucurbit fruit fly in different traps was $T_5>T_4>T_1> T_3> T_2$ at different fruiting stages (e.g. early, mid and late fruiting stages) of bottle gourd. More or less similar results were also reported by several researchers as Islam (2013), Hossen (2012), Rakshit *et al.* (2011) and Akhtaruzzaman *et al.* (2000). Such as Hossen (2012), who reported that Pheromone trap + Bait trap was most effective in capturing the adult fruit fly. Islam (2013) reported that pheromone trap with bait trap showed the best performance in capturing adult cucurbit fruit fly. This result was supported by Alam *et al.* (2020) found the pheromone trap was the best in capturing Fruit fly in the experimental field.

4.2. Fruit infestation by number of bottle gourd

4.2.1. At the early fruiting stage

At the early fruiting stage of bottle gourd, the consequence of different traps on the percent fruit infestation by number has been shown in Table 3. From this table it was revealed that, the highest number of healthy fruits per plot (10.07 fruits) was recorded from T_5 (Pheromone trap + Bait trap with sweet gourd mashed) treatment, which was significantly different from all other treatments and followed by 9.43 and 9.03 in T_4 (Pheromone trap + Bait trap with banana mashed) and T_1 (Pheromone trap), respectively; whereas the lowest number of healthy fruit (6.33 fruits) was recorded in T_6 (untreated control) which was closely followed by 7.76 and 8.63 in T_2 (Bait trap with banana mashed) and T_3 (Bait trap with sweet gourd mashed) treatments, respectively. In the same way, the lowest number of infested fruits per plot (0.36 fruits) was recorded from T_5 (Pheromone trap + Bait trap with sweet gourd mashed) treatment, which was significantly similar with 0.47 in T_4 (Pheromone trap + Bait trap with banana mashed) and followed by 0.69 in T_1 (Pheromone trap); whereas the highest number of infested fruit (1.46 fruits) was recorded in T_6 (untreated control) which was closely followed by 1.03 and 0.88 in T_2 (Bait trap with banana mashed) and T_3 (Bait trap with sweet gourd mashed) treatments, respectively.

In terms of percent fruit infestation by number, the lowest percent fruit infestation by number (3.57%) was recorded from T_5 (Pheromone trap + Bait trap with sweet gourd mashed) treatment, which was significantly different from other treatments and followed by 4.98 and 7.64 in T_4 (Pheromone trap + Bait trap with banana mashed) and T_1(Pheromone trap) treatments, respectively; whereas the highest percent of fruit infestation by number (23.06%) was recorded in T_6 (untreated control) which was statistically different from other treatments and followed by 13.27 and 10.20 in T_2 (Bait trap with banana mashed) and T_3 (Bait trap with sweet gourd mashed) treatments, respectively.

In case of percent fruit infestation reduction over control, the highest percent reduction over control (84.50%) was recorded from T_5 (Pheromone trap + Bait trap with sweet gourd mashed) treatment, and followed by 78.39 and 66.87 in T_4 (Pheromone trap + Bait trap with banana mashed) and T_1 (Pheromone trap) treatments, respectively; whereas the lowest percent reduction over control (42.45%) was recorded in T_2 (Bait trap with banana mashed) which was followed by 55.79% in and T_3 (Bait trap with sweet gourd mashed) treatment.

Table 3. Effects of different treatments on the fruit infestation by number of bottle gourd at early fruiting stage

Treatments	Number of healthy fruits	Number of infested fruits	% fruit infestation	% reduction over control
T_1	9.03 bc	0.69 c	7.64 d	66.87
T_2	7.76 e	1.03 b	13.27 b	42.45
T_3	8.63 d	0.88 bc	10.20 c	55.79
T_4	9.43 b	0.47 d	4.98 e	78.39
T_5	10.07 a	0.36 d	3.57 f	84.50
T_6	6.33 f	1.46 a	23.06 a	0.00
CV(%)	4.87	7.79	5.56	
$LSD_{(0.05)}$	0.56	0.36	1.07	

[In a column, numeric value represents the mean of 3 replications; each replication is derived from plot per treatment; in a column means having similar letter(s) are statistically identical at 0.05 level of probability.

Here, T_1 = Using Pheromone trap; T_2 = Using Bait trap with Banana mashed at the 5 days interval; T_3 = Using Bait trap with sweet gourd mashed at the 5 days interval; T_4 = Using Pheromone trap + Using Bait trap with Banana mashed at the 5 days interval; T_5 = Using Pheromone trap + Using Bait trap with sweet gourd mashed at the 5 days interval; T_6 = Untreated control]

From the results in table 3 showed significant variations due to the effect of different traps on percent fruit infestation by number caused by *B. cucurbitae* at the early fruiting stage of bottle gourd. Among different traps, T_5 (Pheromone trap + Bait trap with sweet gourd mashed) showed more reduction (84.50%) of infestation due to cucurbit fruit fly and supported to make sure the more yield of bottle gourd. As a result, the order of efficacy of different traps in terms of percent fruit infestation by number at early fruiting stage was $T_5 > T_4 > T_1 > T_3 > T_2 > T_6$.This result was supported by Sohel *et al.*(2018) found funnel pheromone trap was the best in controlling fruit fly at early reproductive stage of bottle gourd. Also Islam (2013) reported that pheromone trap with bait trap showed the best performance in controlling fruit fly at early fruiting stage.

4.2.2. At the mid fruiting stage

At the mid fruiting stage of bottle gourd, the consequence of different traps on the percent fruit infestation by number has been shown in Table 4. From this table it was revealed that, the highest number of healthy fruits per plot (12.33 fruits) was recorded from T_5 (Pheromone trap + Bait trap with sweet gourd mashed) treatment, which was significantly different from all other treatments and followed by 11.87 and 11.44 in T_4 (Pheromone trap + Bait trap with banana mashed) and T_1 (Pheromone trap), respectively; whereas the lowest number of healthy fruit (7.69 fruits) was recorded in T_6 (untreated control) which was closely followed by 9.87 and 10.67 in T_2 (Bait trap with banana mashed) and T_3 (Bait trap with sweet gourd mashed) treatments, respectively.

In the same way, the lowest number of infested fruits per plot (0.39 fruits) was recorded from T_5 (Pheromone trap + Bait trap with sweet gourd mashed) treatment, which was significantly similar with 0.42 in T_4 (Pheromone trap + Bait trap with banana mashed) and followed by 0.66 in T_1 (Pheromone trap); whereas the highest number of infested fruit (1.09 fruits) was recorded in T_6 (untreated control) which was closely followed by 0.88 and 0.79 in T_2 (Bait trap with banana mashed) and T_3 (Bait trap with sweet gourd mashed) treatments, respectively.

In terms of percent fruit infestation by number, the lowest percent fruit infestation by number (3.16%) was recorded from T_5 (Pheromone trap + Bait trap with sweet gourd mashed) treatment, which was significantly similar with 3.54 in T_4 (Pheromone trap + Bait trap with banana mashed) and followed by 5.77 in T_1 (Pheromone trap) treatments; whereas the lowest percent of fruit infestation by number (14.17%) was recorded in T_6 (untreated control) which was statistically different from other treatments and followed by 8.92 and 7.40 in T_2 (Bait trap with banana mashed) and T_3 (Bait trap with sweet gourd mashed) treatments, respectively.

In case of fruit infestation percent reduction over control, the highest percent reduction over control (77.68%) was recorded from T_5 (Pheromone trap + Bait trap with sweet gourd mashed) treatment, and followed by 75.04 and 59.30 in T_4 (Pheromone trap + Bait trap with banana mashed) and T_1 (Pheromone trap) treatments, respectively; whereas the lowest percent reduction over control (37.10%) was recorded in T_2 (Bait trap with banana mashed) which was followed by 47.76% in T_3 (Bait trap with sweet gourd mashed) treatment.

Table 4. Effects of different treatments on the fruit infestation by number of bottle gourd at mid fruiting stage

Treatments	Number of healthy fruits	Number of infested fruits	% fruit infestation	% reduction over control
T_1	11.44 c	0.66 bc	5.77 d	59.30
T_2	9.87 e	0.88 ab	8.92 b	37.10
T_3	10.67 d	0.79 b	7.40 c	47.76
T_4	11.87 b	0.42 d	3.54 e	75.04
T_5	12.33 a	0.39 d	3.16 e	77.68
T_6	7.69 f	1.09 a	14.17 a	0.00
CV(%)	6.42	9.27	4.53	
$LSD_{(0.05)}$	0.56	0.23	1.17	

[In a column, numeric value represents the mean of 3 replications; each replication is derived from plot per treatment; in a column means having similar letter(s) are statistically identical at 0.05 level of probability.

Here, T_1 = Using Pheromone trap; T_2 = Using Bait trap with Banana mashed at the 5 days interval; T_3 = Using Bait trap with sweet gourd mashed at the 5 days interval; T_4 = Using Pheromone trap + Using

Bait trap with Banana mashed at the 5 days interval; T_5 = Using Pheromone trap + Using Bait trap with sweet gourd mashed at the 5 days interval; T_6 = Untreated control]

The results illustrated in Table 4 showed significant variations due to the effect of different traps on percent fruit infestation by number caused by *B. cucurbitae* at the mid fruiting stage of bottle gourd. Among different traps, T_5 (Pheromone trap + Bait trap with sweet gourd mashed) showed more reduction (77.68%) of infestation due to cucurbit fruit fly and supported to make sure the more yield of bottle gourd. As a result, the order of efficacy of different traps in terms of percent fruit infestation by number at mid fruiting stage was T_5> T_4> T_1> T_3> T_2> T_6. This result was partially supported by Sohel *et al.* (2018) found funnel pheromone trap was the best and pheromone trap was the good performance in controlling fruit fly at mid reproductive stage of bottle gourd. Islam (2013) who found that pheromone trap with bait trap showed the best performance in controlling cucurbit fruit fly at mid fruiting stage.

4.2.3. At the late fruiting stage

At the late fruiting stage of bottle gourd, the consequence of different traps on the percent fruit infestation by number has been shown in Table 5. From this table it was revealed that, the highest number of healthy fruits per plot (10.13 fruits) was recorded from T_5 (Pheromone trap + Bait trap with sweet gourd mashed) treatment, which was significantly different from the all others treatment and followed by 9.44 and 8.79 in T_4 (Pheromone trap + Bait trap with banana mashed) and T_1 (Pheromone trap), respectively; whereas the lowest number of healthy fruit (5.47 fruits) was recorded in T_6 (untreated control) which was followed by 6.67 and 7.67 in T_2 (Bait trap with banana mashed) and T_3 (Bait trap with sweet gourd mashed) treatments, respectively.

In the same way, the lowest number of infested fruits per plot (0.69 fruits) was recorded from T_5 (Pheromone trap + Bait trap with sweet gourd mashed) treatment, which was significantly similar with 0.87 in T_4 (Pheromone trap + Bait trap with banana mashed) and followed by 0.98 in T_1 (Pheromone trap); whereas the highest number of infested fruit (1.59 fruits) was recorded in T_6 (untreated control) which was closely followed by 1.23 and 1.13 in T_2 (Bait trap with banana mashed) and T_3 (Bait trap with sweet gourd mashed) treatments, respectively.

In terms of percent fruit infestation by number, the lowest percent fruit infestation by number (6.81%) was recorded from T_5 (Pheromone trap + Bait trap with sweet gourd mashed) treatment, which was significantly different from other treatments and followed by 9.22 and 11.15 in T_4 (Pheromone trap + Bait trap with banana mashed) and T_1 (Pheromone trap) treatments, respectively; whereas the highest percent of fruit infestation by number (29.07%) was recorded in T_6 (untreated control) which was statistically different from other treatments and followed by 18.44 and 14.73 in T_2 (Bait trap with banana mashed) and T_3 (Bait trap with sweet gourd mashed) treatments, respectively.

In case of fruit infestation percent reduction over control, the highest percent reduction over control (76.57%) was recorded from T_5 (Pheromone trap + Bait trap with sweet gourd mashed) treatment, and followed by 68.29 and 61.64 in T_4 (Pheromone trap + Bait trap with banana mashed) and T_1 (Pheromone trap) treatments, respectively; whereas the lowest percent reduction over control (36.56%) was recorded in T_2 (Bait trap with banana mashed) which was followed by 49.32% in T_3 (Bait trap with sweet gourd mashed) treatment.

Table 5. Effects of different treatments on the fruit infestation by number of bottle gourd at late fruiting stage

Treatments	Number of healthy fruits	Number of infested fruits	% fruit infestation	% reduction over control
T_1	8.79 c	0.98 d	11.15 d	61.64
T_2	6.67 e	1.23 b	18.44 b	36.56
T_3	7.67 d	1.13 c	14.73 c	49.32
T_4	9.44 b	0.87 de	9.22 e	68.29
T_5	10.13 a	0.69 e	6.81 f	76.57
T_6	5.47 f	1.59 a	29.07 a	0.00
CV(%)	5.89	4.48	3.78	
$LSD_{(0.05)}$	0.43	0.39	0.64	

[In a column, numeric value represents the mean of 3 replications; each replication is derived from plot per treatment; in a column means having similar letter(s) are statistically identical at 0.05 level of probability.

Here, T_1 = Using Pheromone trap; T_2 = Using Bait trap with Banana mashed at the 5 days interval; T_3 = Using Bait trap with sweet gourd mashed at the 5 days interval; T_4 = Using Pheromone trap + Using Bait trap with Banana mashed at the 5 days interval; T_5 = Using Pheromone trap + Using Bait trap with sweet gourd mashed at the 5 days interval; T_6 = Untreated control]

The results in Table 5 showed significant variations due to the effect of different traps on percent fruit infestation by number caused by *B. cucurbitae* at the late fruiting stage of bottle gourd. Among different traps, T_5 (Pheromone trap + Bait trap with sweet gourd mashed) showed more reduction (76.57%) of infestation due to cucurbit fruit fly and supported to make sure the more yield of bottle gourd. As a result, the order of efficacy of different traps in terms of percent fruit infestation by number at late fruiting stage was $T_5 > T_4 > T_1 > T_3 > T_2 > T_6$. This result was supported by Sohel *et al.* (2018) who found that funnel pheromone trap gave the best in controlling fruit fly at late reproductive stage of bottle gourd. Alam *et al.* (2020) found pheromone trap was the best in controlling fruit fly in bottle gourd. Islam (2013) also found pheromone trap with bait trap as the most effective in controlling fruit fly at late fruiting stage.

4.3. Fruit infestation by weight of bottle gourd

4.3.1. At the early fruiting stage

At the early fruiting stage of bottle gourd, the consequence of different traps on the percent fruit infestation by weight has been shown in Table 6. From this table it was revealed that, the highest weight of healthy fruits per plot (25.77 Kg) was recorded from T_5 (Pheromone trap + Bait trap with sweet gourd mashed) treatment, which was significantly different from all other treatments and followed by 23.65 and 20.76 in T_4 (Pheromone trap + Bait trap with banana mashed) and T_1 (Pheromone trap), respectively; whereas the lowest weight of healthy fruit (16.37 Kg) was recorded in T_6 (untreated control) which was closely followed by 18.87 and 21.13 in T_2 (Bait trap with banana mashed) and T_3 (Bait trap with sweet gourd mashed) treatments, respectively.

In the same way, the lowest weight of infested fruits per plot (1.11 Kg) was recorded from T_5 (Pheromone trap + Bait trap with sweet gourd mashed) treatment, which was significantly similar with 1.21 in T_4 (Pheromone trap + Bait trap with banana mashed) and followed by 1.67 and 1.76 in T_1 (Pheromone trap) and T_3 (Bait trap with sweet gourd mashed) treatments, respectively; whereas the highest weight of infested fruit (2.87 Kg) was recorded in T_6 (untreated control) which was closely followed by 2.33 in T_2 (Bait trap with banana mashed) treatment.

In terms of percent fruit infestation by weight, the lowest percent fruit infestation by weight (4.31%) was recorded from T_5 (Pheromone trap + Bait trap with sweet gourd mashed) treatment, which was significantly different from other treatments and followed by 5.12 and 7.90 in T_4 (Pheromone trap + Bait trap with banana mashed) and T_1(Pheromone trap) treatments, respectively; whereas the highest percent of fruit infestation by weight (17.53%) was recorded in T_6 (untreated control) which was statistically different from other treatments and followed by 12.35 and 8.48 in T_2 (Bait trap with banana mashed) and T_3 (Bait trap with sweet gourd mashed) treatments, respectively.

In case of fruit infestation percent reduction over control, the highest percent reduction over control (75.43%) was recorded from T_5 (Pheromone trap + Bait trap with sweet gourd mashed) treatment, and followed by 70.82 and 54.92 in T_4 (Pheromone trap + Bait trap with banana mashed) and T_1 (Pheromone trap) treatments, respectively; whereas the lowest percent reduction over control (29.57%) was recorded in T_2 (Bait trap with banana mashed) which was followed by 51.64% in and T_3 (Bait trap with sweet gourd mashed) treatment.

Table 6. Effects of different treatments on the fruit infestation by weight of bottle gourd at early fruiting stage

Treatments	Weight of healthy fruits (Kg)	Weight of infested fruits (Kg)	% fruit infestation	% reduction over control
T_1	21.13 c	1.67 c	7.90 d	54.92
T_2	18.87 d	2.33 b	12.35 b	29.57
T_3	20.76 c	1.76 c	8.48 c	51.64
T_4	23.65 b	1.21 d	5.12 e	70.82
T_5	25.77 a	1.11 d	4.31 f	75.43
T_6	16.37 e	2.87 a	17.53 a	0.00
CV(%)	5.87	7.79	6.23	
$LSD_{(0.05)}$	1.13	0.39	0.67	

[In a column, numeric value represents the mean of 3 replications; each replication is derived from plot per treatment; in a column means having similar letter(s) are statistically identical at 0.05 level of probability.

Here, T_1 = Using Pheromone trap; T_2 = Using Bait trap with Banana mashed at the 5 days interval; T_3 = Using Bait trap with sweet gourd mashed at the 5 days interval; T_4 = Using Pheromone trap + Using Bait trap with Banana mashed at the 5 days interval; T_5 = Using Pheromone trap + Using Bait trap with sweet gourd mashed at the 5 days interval; T_6 = Untreated control]

The results in Table 6 showed significant variations due to the effect of different traps on percent fruit infestation by weight caused by *B. cucurbitae* at the early fruiting stage of bottle gourd. Among different traps, T_5 (Pheromone trap + Bait trap with sweet gourd mashed) showed more reduction (75.43%) of infestation due to cucurbit fruit fly and supported to make sure the more yield of bottle gourd. As a result, the order of efficacy of different traps in terms of percent fruit infestation by weight at early fruiting stage was T_5> T_4> T_1> T_3> T_2> T_6. This result was supported by Sohel *et al*. (2018) who found the funnel pheromone trap performed the best to control fruit fly at early reproductive stage of bottle gourd. Islam (2013) also found that the pheromone trap with bait trap was the best weight of bottle gourd at early fruiting stage.

4.3.2. At the mid fruiting stage

At the mid fruiting stage of bottle gourd, the consequence of different traps on the percent fruit infestation by weight has been shown in Table 7. From this table it was revealed that, the highest weight of healthy fruits per plot (36.67 Kg) was recorded from T_5 (Pheromone trap + Bait trap with sweet gourd mashed) treatment, which was significantly different from all other treatments and followed by 34.46 and 32.76 in T_4 (Pheromone trap + Bait trap with banana mashed) and T_1 (Pheromone trap), respectively; whereas the lowest weight of healthy fruit (21.46 Kg) was recorded in T_6 (untreated control) which was closely followed by 26.57 and 30.33 in T_2 (Bait trap with banana mashed) and T_3 (Bait trap with sweet gourd mashed) treatments, respectively.

In the same way, the lowest weight of infested fruits per plot (2.23 Kg) was recorded from T_5 (Pheromone trap + Bait trap with sweet gourd mashed) treatment, which was significantly different from others and followed by 2.72 and 3.13 in T_4 (Pheromone trap + Bait trap with banana mashed) and T_1 (Pheromone trap) treatments, respectively; whereas the highest weight of infested fruit (4.67 Kg) was recorded in T_6

(untreated control) which was statistically similar with T_2 (Bait trap with banana mashed) (4.11 Kg) and closely followed by 3.56 in T_3 (Bait trap with sweet gourd mashed) treatment.

In terms of percent fruit infestation by weight, the lowest percent fruit infestation by weight (6.08%) was recorded from T_5 (Pheromone trap + Bait trap with sweet gourd mashed) treatment, which was significantly different from others and followed by7.89 and 9.55 in T_4 (Pheromone trap + Bait trap with banana mashed) and T_1(Pheromone trap) treatments, respectively; whereas the highest percent of fruit infestation by weight (21.76%) was recorded in T_6 (untreated control) which was statistically different from other treatments and followed by 15.47 and 11.74 in T_2 (Bait trap with banana mashed) and T_3 (Bait trap with sweet gourd mashed) treatments, respectively.

In case of fruit infestation percent reduction over control, the highest percent reduction over control (72.05%) was recorded from T_5 (Pheromone trap + Bait trap with sweet gourd mashed) treatment, and followed by 63.73 and 56.10 in T_4 (Pheromone trap + Bait trap with banana mashed) and T_1 (Pheromone trap) treatments, respectively; whereas the lowest percent reduction over control (28.92%) was recorded in T_2 (Bait trap with banana mashed) which was followed by 46.06% in T_3 (Bait trap with sweet gourd mashed) treatment.

Table 7. Effects of different treatments on the fruit infestation by weight of bottle gourd at mid fruiting stage

Treatments	Weight of healthy fruits (Kg)	Weight of infested fruits (Kg)	% fruit infestation	% reduction over control
T_1	32.76 c	3.13 c	9.55 d	56.10
T_2	26.57 e	4.11 a	15.47 b	28.92
T_3	30.33 d	3.56 b	11.74 c	46.06
T_4	34.46 b	2.72 d	7.89 e	63.73
T_5	36.67 a	2.23 e	6.08 f	72.05
T_6	21.46 f	4.67 a	21.76 a	0.00
CV(%)	5.47	7.59	5.87	
$LSD_{(0.05)}$	1.44	0.54	1.13	

[In a column, numeric value represents the mean of 3 replications; each replication is derived from plot per treatment; in a column means having similar letter(s) are statistically identical at 0.05 level of probability.

Here, T_1 = Using Pheromone trap; T_2 = Using Bait trap with Banana mashed at the 5 days interval; T_3 = Using Bait trap with sweet gourd mashed at the 5 days interval; T_4 = Using Pheromone trap + Using Bait trap with Banana mashed at the 5 days interval; T_5 = Using Pheromone trap + Using Bait trap with sweet gourd mashed at the 5 days interval; T_6 = Untreated control]

The results in Table 7 showed significant variations due to the effect of different traps on percent fruit infestation by weight caused by *B. cucurbitae* at the mid fruiting stage of bottle gourd. Among different traps, T_5 (Pheromone trap + Bait trap with sweet gourd mashed) showed more reduction (72.05%) of infestation due to cucurbit fruit fly and supported to make sure the more yield of bottle gourd. As a result, the order of efficacy of different traps in terms of percent fruit infestation by weight at mid fruiting stage is $T_5 > T_4 > T_1 > T_3 > T_2 > T_6$.This result was supported by Sohel *et al.* (2018) who found funnel pheromone trap was the best against fruit fly at mild reproductive stage of bottle gourd. Also Islam (2013) found the pheromone trap with bait trap was the best weight of bottle gourd at mid fruiting stage.

4.3.3. At the late fruiting stage

At the late fruiting stage of bottle gourd, the consequence of different traps on the percent fruit infestation by weight has been shown in Table 8. From this table it was revealed that, the highest weight of healthy fruits per plot (34.87 Kg) was recorded from T_5 (Pheromone trap + Bait trap with sweet gourd mashed) treatment, which was significantly different from all other treatments and followed by 32.37 and 31.46 in T_4 (Pheromone trap + Bait trap with banana mashed) and T_1(Pheromone trap), respectively; whereas the lowest weight of healthy fruit (24.33 Kg) was recorded in T_6 (untreated control) which was followed by 28.17 and 29.89 in T_2 (Bait trap with banana mashed) and T_3 (Bait trap with sweet gourd mashed) treatments, respectively.

In the same way, the lowest weight of infested fruits per plot (2.09 Kg) was recorded from T_5 (Pheromone trap + Bait trap with sweet gourd mashed) treatment, which was significantly different from others and followed by2.67 and 3.21 in T_4 (Pheromone trap + Bait trap with banana mashed) and T_1 (Pheromone trap) treatments, respectively; whereas the highest weight of infested fruit (4.07 Kg) was recorded in T_6 (untreated control) which was closely followed by 3.56 and 3.33 in T_2 (Bait trap with banana mashed) and T_3 (Bait trap with sweet gourd mashed) treatments, respectively.

In terms of percent fruit infestation by weight, the lowest percent fruit infestation by weight (5.99%) was recorded from T_5 (Pheromone trap + Bait trap with sweet gourd mashed) treatment, which was significantly different from other treatments and followed by 8.25 and 10.20 in T_4 (Pheromone trap + Bait trap with banana mashed) and T_1 (Pheromone trap) treatments, respectively; whereas the highest percent of fruit infestation by number (16.73%) was recorded in T_6 (untreated control) which was statistically different from other treatments and followed by 12.64 and 11.14 in T_2 (Bait trap with banana mashed) and T_3 (Bait trap with sweet gourd mashed) treatments, respectively.

In case of fruit infestation percent reduction over control, the highest percent reduction over control (64.17%) was recorded from T_5 (Pheromone trap + Bait trap with sweet gourd mashed) treatment, and followed by 50.69 and 39.01 in T_4 (Pheromone trap + Bait trap with banana mashed) and T_1 (Pheromone trap) treatments, respectively; whereas the lowest percent reduction over control (24.45%) was recorded in T_2 (Bait trap with banana mashed) which was followed by 33.40% in T_3 (Bait trap with sweet gourd mashed) treatment.

Table 8. Effects of different treatments on the fruit infestation by weight of bottle gourd at late fruiting stage

Treatments	Weight of healthy fruits (Kg)	Weight of infested fruits (Kg)	% fruit infestation	% reduction over control
T_1	31.46 c	3.21 c	10.20 cd	39.01
T_2	28.17 e	3.56 b	12.64 b	24.45
T_3	29.89 d	3.33 bc	11.14 c	33.40
T_4	32.37 b	2.67 d	8.25 e	50.69
T_5	34.87 a	2.09 e	5.99 f	64.17
T_6	24.33 f	4.07 a	16.73 a	0.00
CV(%)	1.11	0.43	1.23	
$LSD_{(0.05)}$	4.57	5.43	4.98	

[In a column, numeric value represents the mean of 3 replications; each replication is derived from plot per treatment; in a column means having similar letter(s) are statistically identical at 0.05 level of probability.

Here, T_1 = Using Pheromone trap; T_2 = Using Bait trap with Banana mashed at the 5 days interval; T_3 = Using Bait trap with sweet gourd mashed at the 5 days interval; T_4 = Using Pheromone trap + Using Bait trap with Banana mashed at the 5 days interval; T_5 = Using Pheromone trap + Using Bait trap with sweet gourd mashed at the 5 days interval; T_6 = Untreated control]

The results in Table 8 showed significant variations due to the effect of different traps on percent fruit infestation by weight caused by *B. cucurbitae* at the late fruiting stage of bottle gourd. Among different traps, T_5 (Pheromone trap + Bait trap with sweet gourd mashed) showed more reduction (64.17%) of infestation due to cucurbit fruit fly and supported to make sure the more yield of bottle gourd. As a result, the order of efficacy of different traps in terms of percent fruit infestation by weight at late fruiting stage was T_5> T_4> T_1> T_3> T_2> T_6.This result was supported by Sohel *et al.* (2018) who found funnel pheromone trap was the best against fruit fly at late reproductive stage in bottle gourd. Islam (2013) also found the pheromone trap with bait trap was the best against fruit fly at late fruiting stage. Alam (2018) found the pheromone trap as the best weight in bottle gourd experimental field.

4.4. Yield attributing characteristics

Length of fruit: The impact of different traps on length of healthy fruits of bottle gourd has been shown in Table 9. Significant variations were observed among the treatments in terms of length of healthy fruits. The highest length of single fruit (54.87 cm) was recorded in T_5 (Pheromone trap + Bait trap with sweet gourd mashed) treatment, which was significantly similar with 54.33 in T_4 (Pheromone trap + Bait trap with banana mashed) and followed by 53.76 and 53.43 in T_1 (Pheromone trap) and T_3 (Bait trap with sweet gourd mashed) treatments, respectively; whereas the lowest length of single fruit (50.67 cm) was recorded in T_6 (untreated control) which was closely followed by 52.89 in T_2 (Bait trap with banana mashed) treatment.

Girth of fruit: The impact of different traps on girth of healthy fruits of bottle gourd has been shown in Table 9. Significant variations were observed among the treatments in terms of girth of healthy fruits. The highest girth of single fruit (24.37 cm) was recorded in T_5 (Pheromone trap + Bait trap with sweet gourd mashed) treatment, which was significantly similar with 24.11 in T_4 (Pheromone trap + Bait trap with banana mashed) and followed by 22.57 and 22.17 in T_1 (Pheromone trap) and T_3 (Bait trap with sweet gourd mashed) treatments, respectively; whereas the lowest girth of single fruit (20.43 cm) was recorded in T_6 (untreated control) which was closely followed by 21.51 in T_2 (Bait trap with banana mashed) treatment.

Single fruit weight: The impact of different traps on single fruit weight of healthy fruits of bottle gourd has been shown in Table 9. Significant variations were observed among the treatments in terms of single fruit weight of healthy fruits. The highest weight of single fruit (2.59 Kg) was recorded in T_5 (Pheromone trap + Bait trap with sweet gourd mashed) treatment, which was significantly similar with 2.23 in T_4 (Pheromone trap + Bait trap with banana mashed) and followed by 2.11 in T_1 (Pheromone trap) treatment; whereas the lowest weight of single fruit (1.31 Kg) was recorded in T_6 (untreated control) which was closely followed by 1.53 and 1.67 in T_2 (Bait trap with banana mashed) and T_3 (Bait trap with sweet gourd mashed) treatments, respectively.

Table 9. Effect of different traps against cucurbit fruit fly and its impact on yield contributing characters of bottle gourd

Treatments	Fruit length (cm)	Fruit girth (cm)	Single fruit weight (Kg)
T_1	53.76 b	22.57 b	2.11 b
T_2	52.89 c	21.51 d	1.53 c
T_3	53.43 b	22.17 c	1.67 c
T_4	54.33 a	24.11 a	2.23 ab
T_5	54.87 a	24.37 a	2.59 a
T_6	50.67 d	20.43 e	1.31 d
CV(%)	5.27	4.69	3.78
$LSD_{(0.05)}$	0.97	0.43	0.38

[In a column, numeric value represents the mean of 3 replications; each replication is derived from plot per treatment; in a column means having similar letter(s) are statistically identical at 0.05 level of probability.

Here, T_1 = Using Pheromone trap; T_2 = Using Bait trap with Banana mashed at the 5 days interval; T_3 = Using Bait trap with sweet gourd mashed at the 5 days interval; T_4 = Using Pheromone trap + Using Bait trap with Banana mashed at the 5 days interval; T_5 = Using Pheromone trap + Using Bait trap with sweet gourd mashed at the 5 days interval; T_6 = Untreated control]

The results in Table 9 showed significant variations due to the effect of different traps on healthy fruit length, healthy fruit girth and single fruit weight of bottle gourd. Among different traps, T_5 (Pheromone trap + Bait trap with sweet gourd mashed) showed the best performance among healthy fruit length, healthy fruit girth and single fruit weight of bottle gourd. As a result, the order of efficacy of different traps in terms of healthy fruit length, healthy fruit girth and single fruit weight was $T_5 > T_4 > T_1 > T_3 > T_2 > T_6$. This result was supported by Sohel *et al*. (2018) found the funnel pheromone trap performed the best against from fruit fly and also found the highest healthy fruit length, healthy fruit girth and single fruit weight of bottle gourd in this treatment.

4.5. Yield of bottle gourd

The impact of different traps on yield of bottle gourd has been shown in Table 10. Significant variations were observed among the treatments in terms of yield of bottle gourd. The highest yield of bottle gourd (71.37 t/ha) was recorded in T_5 (Pheromone trap + Bait trap with sweet gourd mashed) treatment, which was significantly different from other treatments and followed by 69.76 in T_4 (Pheromone trap + Bait trap with banana mashed) treatment; whereas the lowest yield of bottle gourd (61.33 t/ha) was recorded in T_6 (untreated control) which was followed by 67.67, 68.13 and 68.46 in T_2 (Bait trap with banana mashed), T_3 (Bait trap with sweet gourd mashed) and T_1 (Pheromone trap) treatments, respectively.

In case of yield increase over control, the highest percent increase over control (16.37%) was recorded from T_5 (Pheromone trap + Bait trap with sweet gourd mashed) treatment, and followed by 13.75 and 11.63 in T_4 (Pheromone trap + Bait trap with banana mashed) and T_1 (Pheromone trap) treatments, respectively; whereas the lowest percent increase over control (10.34%) was recorded in T_2 (Bait trap with banana mashed) which was followed by 11.09% in T_3 (Bait trap with sweet gourd mashed) treatment.

Table 10: Effect of different traps against cucurbit fruit fly in bottle gourd on the basis of yield/ha during total cropping season

Treatments	Yield (t/ha)	% increase over control
T_1	68.46 c	11.63
T_2	67.67 c	10.34
T_3	68.13 c	11.09
T_4	69.76 b	13.75
T_5	71.37 a	16.37
T_6	61.33 d	0.00
CV(%)	3.89	
$LSD_{(0.05)}$	1.43	

[In a column, numeric value represents the mean of 3 replications; each replication is derived from plot per treatment; in a column means having similar letter(s) are statistically identical at 0.05 level of probability.

Here, T_1 = Using Pheromone trap; T_2 = Using Bait trap with Banana mashed at the 5 days interval; T_3 = Using Bait trap with sweet gourd mashed at the 5 days interval; T_4 = Using Pheromone trap + Using Bait trap with Banana mashed at the 5 days interval; T_5 = Using Pheromone trap + Using Bait trap with sweet gourd mashed at the 5 days interval; T_6 = Untreated control]

From the results in table 10 showed significant variations due to the effect of different traps on yield of bottle gourd. Among different traps, T_5 (Pheromone trap + Bait trap with sweet gourd mashed) showed the best performance in terms of yield of bottle gourd. As a result, the order of efficacy of different traps in terms of yield is T_5> T_4> T_1> T_3> T_2> T_6. This result was supported by Islam (2013) who found the pheromone trap with bait trap performed the best in controlling the Fruit fly as a result the best yield was found from the pheromone trap with bait trap. Sohel *et al*. (2018) reported the best performance of funnel pheromone trap against fruit fly in bottle gourd field during total cropping season.

4.6. Relationship between the fruit infestation by number caused by *B.cucubetae* and yield

4.6.1. Early fruiting stage

Correlation study was done to establish the relationship between the percent fruit infestation by number and yield of bottle gourd at early fruiting stage. From the Figure 1, a negative correlation was observed between the parameters. It was evident

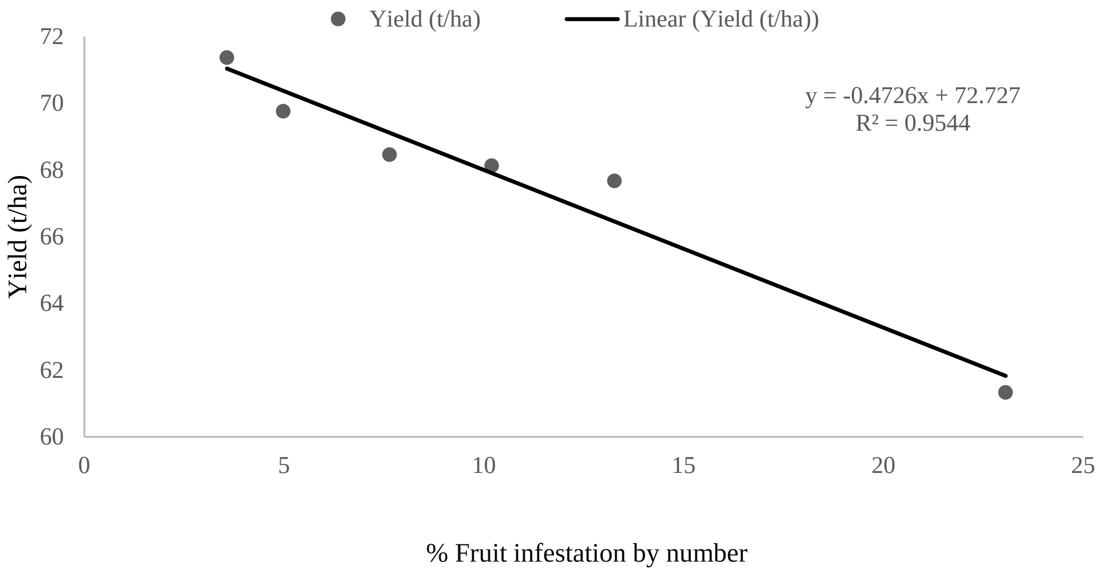

Figure 1: Relationship between percent fruit infestation by number and yield of bottle gourd at early fruiting stage

that, the equation y = - 0.4726x + 72.727 gave a good fit to the data and the co-efficient of determination (R^2 = 0.9544) fitted regression line had a significant regression co-efficient.

It may be concluded from the figure that, the percent of fruit infestation by number was strongly as well as negatively correlate with the yield of bottle gourd at early fruiting stage. Percent of fruit infestation by number at early fruiting stage was increased with the decrease of yield of bottle gourd.

4.6.2. Mid fruiting stage

Correlation study was done to establish the relationship between the percent fruit infestation by number and yield of bottle gourd at mid fruiting stage. From the Figure 2, a negative correlation was observed between the parameters. It was evident that, the equation y = - 0.8136x + 73.612 gave a good fit to the data and the co-efficient of determination (R^2 = 0.9348) fitted regression line had a significant regression co-efficient. It may be concluded from the figure that, the percent of fruit infestation by number was strongly as well as negatively correlated with the yield of bottle gourd at mid fruiting stage. Percent of fruit infestation by number at mid fruiting stage was increased with the decrease of yield of bottle gourd.

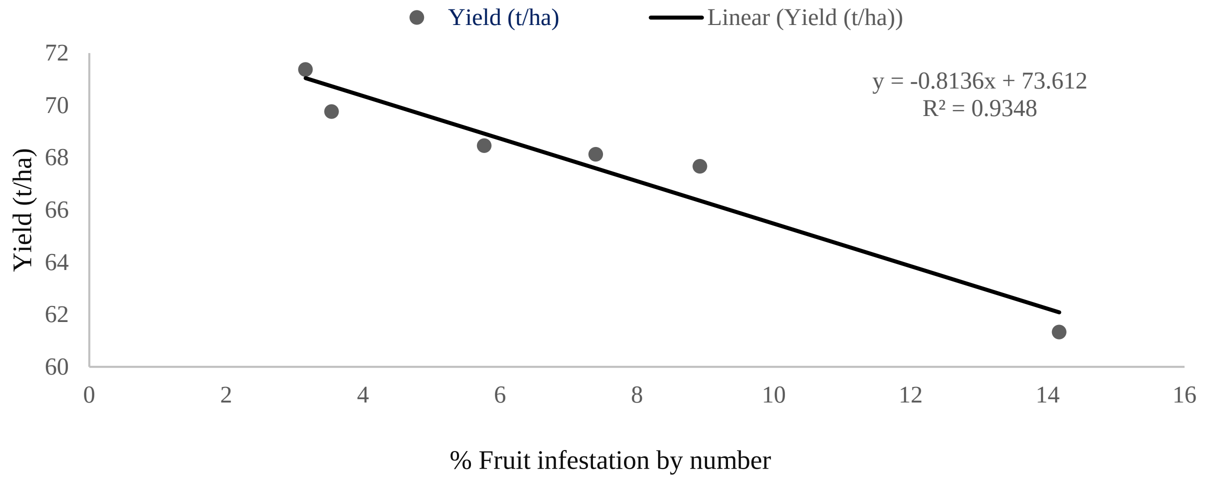

Figure 2: Relationship between percent fruit infestation by number and yield of bottle gourd at mid fruiting stage

4.6.3. Late fruiting stage

Correlation study was done to establish the relationship between the percent fruit infestation by number and yield of bottle gourd at late fruiting stage. From the Figure 3, a negative correlation was observed between the parameters. It was evident that, the

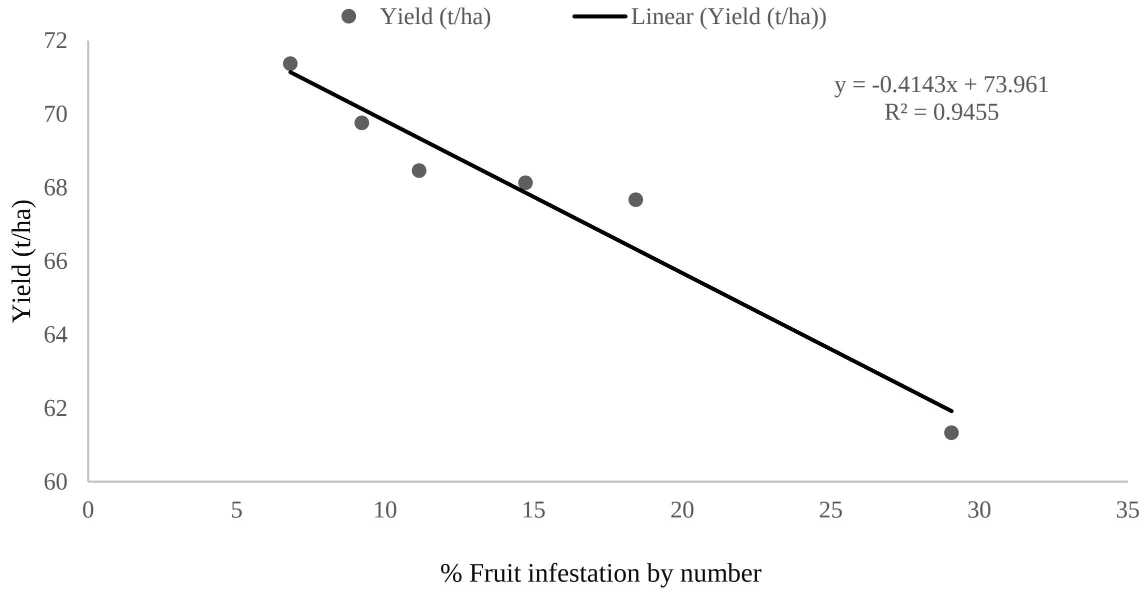

Figure 3: Relationship between percent fruit infestation by number and yield of bottle gourd at late fruiting stage

equation y = - 0.4143x + 73.961 gave a good fit to the data and the co-efficient of determination (R^2 = 0.9455) fitted regression line had a significant regression co-efficient. It may be concluded from the figure that, the percent of fruit infestation by number was strongly as well as negatively correlated with the yield of bottle gourd at late fruiting stage. Percent of fruit infestation by number at late fruiting stage was increased with the decrease of yield of bottle gourd.

4.7. Relationship between the fruit infestation by weight and yield

4.7.1. Early fruiting stage

Correlation study was done to establish the relationship between the percent fruit infestation by weight and yield of bottle gourd at early fruiting stage. From the Figure

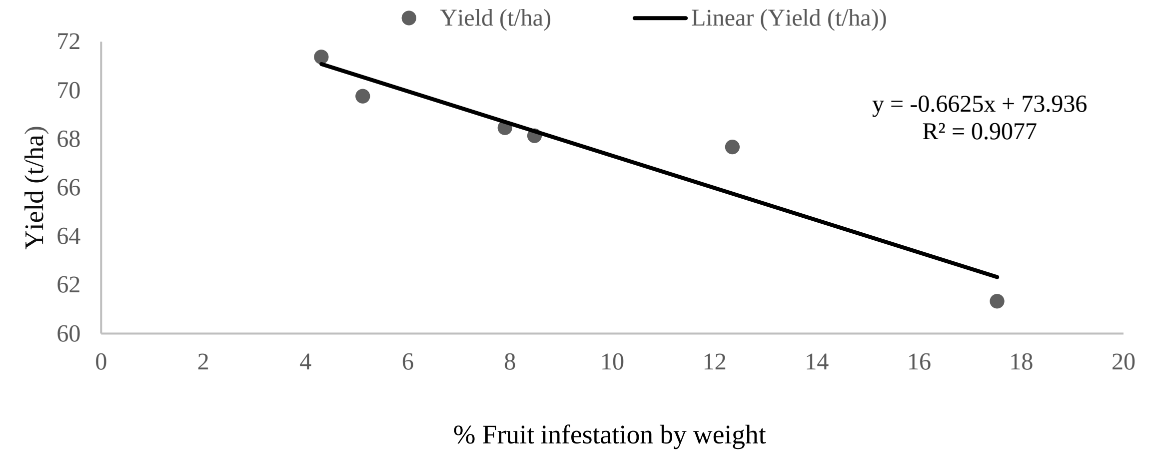

Figure 4: Relationship between percent fruit infestation by weight and yield of bottle gourd at early fruiting stage

4, a negative correlation was observed between the parameters. It was evident that, the equation y = - 0.6625x + 73.936 gave a good fit to the data and the co-efficient of determination (R^2 = 0.9077) fitted regression line had a significant regression co-efficient. It may be concluded from the figure that, the percent of fruit infestation by weight was strongly as well as negatively correlated with the yield of bottle gourd at early fruiting stage. Percent of fruit infestation by weight at early fruiting stage was increased with the decrease of yield of bottle gourd.

4.7.2. Mid fruiting stage

Correlation study was done to establish the relationship between the percent fruit infestation by weight and yield of bottle gourd at mid fruiting stage.

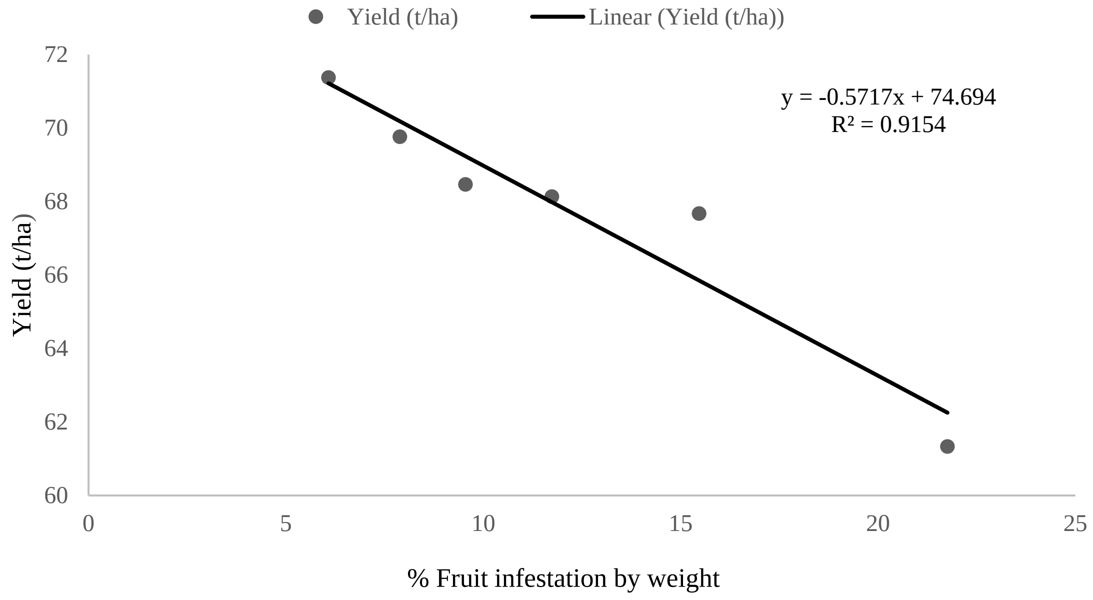

Figure 5: Relationship between percent fruit infestation by weight and yield of bottle gourd at mid fruiting stage

From the Figure 5, a negative correlation was observed between the parameters. It was evident that, the equation y = - 0.5717x + 74.694 gave a good fit to the data and the co-efficient of determination (R^2 = 0.9154) fitted regression line had a significant regression co-efficient. It may be concluded from the figure that, the percent of fruit infestation by weight was strongly as well as negatively correlated with the yield of bottle gourd at mid fruiting stage. Percent of fruit infestation by weight at mid fruiting stage was increased with the decrease of yield of bottle gourd.

4.7.3. Late fruiting stage

Correlation study was done to establish the relationship between the percent fruit infestation by weight and yield of bottle gourd at late fruiting stage. From the Figure 6, a negative correlation was observed between the parameters. It was evident that, the equation y = - 0.8893x + 77.413 gave a good fit to the data and the co-efficient of determination (R^2 = 0.9202) fitted regression line had a significant regression co-efficient. It may be concluded from the figure that, the percent of fruit infestation by weight was strongly as well as negatively correlated with the yield of bottle gourd at late fruiting stage. Percent of fruit infestation by weight at late fruiting

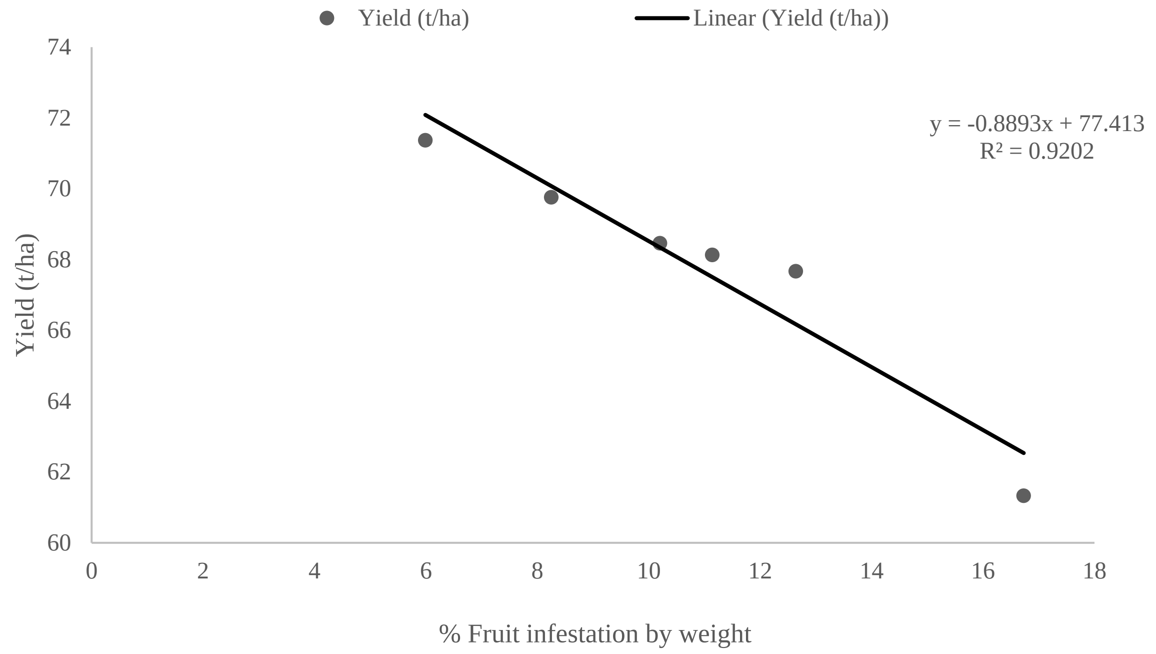

Figure 6: Relationship between percent fruit infestation by weight and yield of bottle gourd at late fruiting stage

stage was increased with the decrease of yield of bottle gourd.

CHAPTER V

SUMMARY AND CONCLUSION

Evaluation of different eco-friendly management practices against fruit fly of bottle gourd was investigated at the field of the Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during the period from October, 2021 to april, 2022. Data on fruit infestation by number, fruit infestation by weight, yield contributing characters and yield were recorded. The summary and conclusion of the study was presented below:

5.1. Summary

There were six treatments including control. Among these treatments, the trend of captured adult cucurbit fruit fly in different traps was T_5>T_4>T_1> T_3> T_2 at different fruiting stages (e.g. early, mid and late fruiting stages) of bottle gourd.

The effect of different traps on percent fruit infestation by number caused by *B. cucurbitae* was observed the different fruiting stage viz. early, mid and late fruiting stage of bottle gourd. Among different traps, T_5 (Pheromone trap + Bait trap with sweet gourd mashed) showed more reduction (84.50%, 77.68% and 76.57%, respectively) of infestation due to cucurbit fruit fly and supported to make sure the more yield of bottle gourd. As a result, the order of efficacy of different traps in terms of percent fruit infestation by number at early, mid and late fruiting stage was T_5> T_4> T_1> T_3> T_2> T_6.

The effect of different traps on percent fruit infestation by weight caused by *B. cucurbitae* was observed at different fruiting stages viz. early, mid and late fruiting stage of bottle gourd. Among different traps, T_5 (Pheromone trap + Bait trap with sweet gourd mashed) showed more reduction (75.43%, 72.05% and 64.17%, respectively) of infestation due to cucurbit fruit fly and supported to make sure the more yield of bottle gourd. As a result, the order of efficacy of different traps in terms of percent fruit infestation by weight at early, mid and late fruiting stage was $T_5 > T_4 > T_1 > T_3 > T_2 > T_6$.

The effect of different traps on healthy fruit length, healthy fruit girth and single fruit weight of bottle gourd was observed. Among different traps, T_5 (Pheromone trap + Bait trap with sweet gourd mashed) showed the best performance among healthy fruit length, healthy fruit girth and single fruit weight of bottle gourd. As a result, the order of efficacy of different traps in terms of healthy fruit length, healthy fruit girth and single fruit weight was $T_5 > T_4 > T_1 > T_3 > T_2 > T_6$.

The effect of different traps on yield of bottle gourd was observed. Among different traps, T_5 (Pheromone trap + Bait trap with sweet gourd mashed) showed the best performance in terms of yield of bottle gourd. As a result, the order of efficacy of different traps in terms of yield was $T_5 > T_4 > T_1 > T_3 > T_2 > T_6$.

5.2. Conclusion

From result of the present study, it may be concluded that the fruit infestation significantly varied among the treatments. The overall study revealed that, the most significant performance was achieved from T_5 (Pheromone trap + Bait trap with sweet gourd mashed). It offered the highest protection from cucurbit fruit fly and gave highest increase in healthy fruit length, girth and the yield.

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

1. The use of pheromone traps should be increased to control cucurbit fruit fly in bottle gourd field to minimize the use of chemical insecticides.
2. Further study is needed in different locations of Bangladesh for accura1cy of the results in different environmental conditions.

CHAPTER VI

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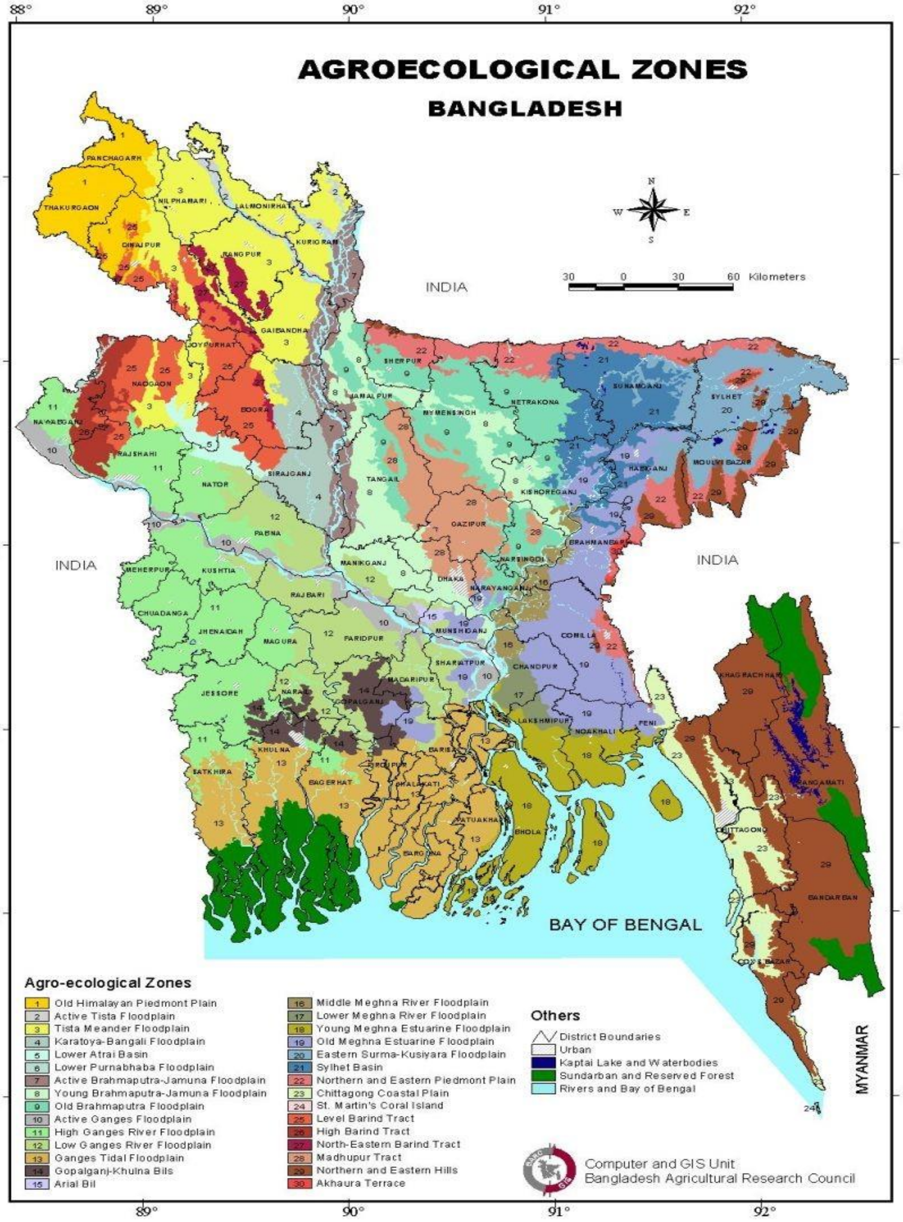
CHAPTER VII

APPENDICES

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



Source: Bangladesh Agricultural Research Council, Khamarbari, Dhaka.

Appendix II. The physical and chemical characteristics of soil the experimental site as observed prior to experimentation (0-15 cm depth).

Mechanical composition:

Soil parameters	Observed values
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.07
Phosphorus	22.08 µg/g soil
Sulphur	25.98 µg/g soil
Magnesium	1.00 mcq/100 g soil
Boron	0.48 µg/g soil
Copper	3.54 µg/g soil
Zinc	3.32 µg/g soil

Source: Soil Resources Development Institute (SRDI), Khamarbari, Dhaka.

Appendix III. Some experimental field pictures are attached here.

Plate 10. Intercultural operation in experimental Field

Plate 11. Preparation of bait trap

Plate 12. Hand pollination

Plate 13. Infestation of flower

Plate 14. Capture of fruit fly in bait trap

Plate 15. Counting of fruit fly