EFFECT OF PHEROMONE TRAPS AND TRAPPING LOCATIONS ON CAPTURING MALE MOTH OF BRINJAL SHOOT AND FRUIT BORER AND FRUIT YIELD OF BRINJAL

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CERTIFICATE

This is to certify that the thesis entitled **“Effect of pheromone traps and trapping locations on capturing male moth of brinjal shoot and fruit borer and fruit yield of brinjal”** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **Master of Science** in **Entomology**, embodies the result of a piece of bonafide research work carried out by **Nibedita Sarker**, Registration number: **13-05774** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated:
Dhaka, Bangladesh

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DEDICATED

TO

MY BELOVED PARENTS

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EFFECT OF PHEROMONE TRAPS AND TRAPPING LOCATIONS ON CAPTURING MALE MOTH OF BRINJAL SHOOT AND FRUIT BORER AND FRUIT YIELD OF BRINJAL

ABSTRACT

The experiment was conducted during the period from November 2013 to April 2014 at the research farm of Sher-e-Bangla Agricultural University (SAU), Dhaka to study the effect of pheromone traps and trapping locations on capturing male moth of brinjal shoot and fruit borer and fruit yield of brinjal. Brinjal variety Shingnath was used as the test crop of this experiment. Four types of pheromone traps were placed at two locations in a two factor Randomized Complete Block Design (RCBD) with three replications. The pheromone traps types were T_1: Funnel type trap; T_2: GME trap; T_3: BARI trap I; T_4: BARI trap II and two locations were L_1: Canopy level and L_2: Upper canopy level. Among differnt traps types GME trap was more effective for catching male moth (6.43 male caught per trap per day), gave the lowest shoot and fruit infestation (5.21%, 5.82%, 6.73% and 4.52%, 5.92%, 6.69%, respectively) at early, mid and late fruiting stages and produced more insect free brinjal fruits (45.36 t/ha). Pheromone traps located at canopy level showed better performance for catching male moth (5.24 male caught per trap per day), and lowest shoot and fruit infestation (8.07%, 10.78, 11.94% and 9.44%, 11.81%, 14.13%, respectively) at different fruiting stages and produced more insect free brinjal fruits (42.92 t/ha). GME traps located at canopy level caught the highest number of male moths, reduced maximum percentage of shoot and fruit infestation and gave more yield of fruits. GME trap and located at canopy position was more effective for the management of brinjal shoot and fruit borer.

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LIST OF ABBREVIATED TERMS

ABBREVIATION	FULL NAME
AEZ	Agro-Ecological Zone
AVRDC	Asian Vegetable Research and Development Center
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
BSFB	Brinjal Shoot and Fruit Borer
cm	Centimeter
DMRT	Duncan’s Multiple Range Test
et al.	and others
etc.	Etcetera
FAO	Food and Agriculture Organization
GME	Graphic Machinery and Equipment
IPM	Integrated Pest Management
LSD	Least Significance Difference
m^2	Square meter
MP	Muriate of Potash
NRI	Natural Resources Institute
RCBD	Randomized Complete Block Design
SAU	Sher-e-Bangla Agricultural University
SRDI	Soil Resources Development Institute
TSP	Triple Super Phosphate
^0C	Degree Celsius

CHAPTER I

INTRODUCTION

Eggplant (*Solanum melongena* L.) is commonly known as brinjal is a self-pollinated annual crop and belongs to the family solanaceae. It is a major vegetable crop throughout the tropic and subtropics (Bose and Som, 1986). Eggplant is the most popular and principal vegetable in Bangladesh, which is extensively cultivated in both Rabi and Kharif seasons. Its annual production in Kharif is scanty and brinjal plays an important role to cover this lean period (Anon., 1994). Brinjal is extensively cultivated in Bangladesh and is grown in homestead and as a field crop in both winter and rainy seasons though bulk of its production is obtained during winter season. More than 20 varieties of eggplants are grown in different regions of the country. Approximately 8.2 million farmers are involved in eggplant cultivation in Bangladesh (Anon., 2012).

The vegetable production in summer is scanty and brinjal plays an important role to meet up the shortage of vegetable in this lean period. Brinjal is the second most important vegetable crop next to potato in Bangladesh in respect of acreage and production (BBS, 2012). The total area of brinjal cultivation is 60,100 hectare where 22,500 ha is grown in Kharif season (summer) and 37,500 ha in Rabi season (winter) with a total annual production of 338,000 metric tons (BBS, 2012). Yield of brinjal is very low in Bangladesh. However, low yielding potentially of this crop may be attributed to a number of reasons, viz. unavailability of quality seeds, land for production based on fertilizer management, improper irrigation and infestation of insect pest. Brinjal is attacked by 53 species of insect pests among which the most obnoxious and detrimental one is the brinjal shoot and fruit borer (BSFB), *Leucinodes orbonalis Guienee* (Lepidoptera: Pyralidae) (Butani and Jotwani, 1984; Nair, 1986; Chattopadhyay, 1987; Tewari and Sandana, 1990). Twenty species of insect pests were found to attack brinjal in field in Bangladesh (Latif *et al*., 2009).

The incidence of the BSFB occurs either sporadically or in outbreak every year affecting the quality and yield of the crop adversely (Dhankar, 1988). Activity of this pest is adversely affected by severe cold but hibernation dose not occur and are active in summer, especially in the rainy season (Kalloo, 1988). The damage by BSFB started at seedling stage and continues till the last harvest of fruits. At early stage of plant growth, the larvae bore into petioles and midrib of large leaves and young shoots, close the entry points with their excreta feed within (Butani and Jotwani, 1984) and cause dropping and withering of shoot (Alam and Sana 1962). At later stage of plant growth, the larvae bore into the flower buds fruits through calyx without leaving any visible sign of infestation (Butani and Jotwani, 1984). Secondary infestation by certain bacteria cause further deterioration of the fruits and the fruits become unfit for human consumption (Islam and Karim, 1994). Incidence of BSFB in brinjal could cause damage as high as 12-16% on shoots and 20-63% on fruits depending on different brinjal varieties, location and season (Alam, 1969). The yield loss due to severe attack of this pest can go up to 80% in Bangladesh (Ali *et al*., 1980).

Despite the importance of brinjal and severity of BSFB problem the management practices to combat BSFB are still limited to frequent sprays of toxic chemical pesticides (Kabir *et al*., 1996). According to pesticides association of Bangladesh, pesticide use for growing Brinjal was 1.41 kg/ha, whereas, for vegetables overall it was 1.12 kg/ha, while it was only 0.20 kg/ha in rice (Anon., 2012). Meanwhile, inappropriate pesticides, incorrect timing of application and improper doses, all have resulted in high pesticides costs with little or no appreciable reduction in target pest populations. The increasing use of synthetic insecticides has lead to a number of problems such as development of resistance to insecticides. High insecticide residues in market produce, resurgence of some insect species due to the destruction of natural predators and parasitoids, changing pest status of mites and other minor insect pests, ecological imbalance and danger to health of the pesticide applicator and to consumers. There are alternative approaches to control this insect pest and use of sex pheromone trap is one of them.

Sex pheromone based management can be considered as the modern technique for the management of BSFB. Pheromone is a term derived from the Greek words ‘Pherein’ to transmit, and Hormone ‘to excite’ (Karlson and Luscher, 1959). This term is used to define the substances secreted to the outside by an individual and perceived by a second individual from the same species, in which they release a specific behavioral reaction, recognition among others (Karlson and Luscher, 1959). The sex pheromone components of BSFB have been identified long back so far no certified efforts have been made to use this aspect in practical management practices of the target pest. Zhu *et al*. (1987) working in china identified (E)-11-hexadecenyl acetate (E11-16: Ac) as the major component of the female sex pheromone of BSFB suggested that it was attracting male moths in the field, although no data was provided. Subsequently, Attygalle *et al*. (1988) confirmed the presence of E11-16: Ac in calling virgin females using insects from Sri Lanka and in addition found trace amount of (E)-11-hexadecen-1-ol (E11-16: OH). However, they did not report the results of any field studies to ascertain the behavioral significance of either of these two compounds. Later on studies undertaken in UK by Natural Resources Institute (NRI) confirmed the presence of large amount of E11-16: AC and trace amount of E11-16: OH in the extracts of ovipositors of female insects sent from Taiwan and India. NRI's other studies in India indicated that a combination of 100: 1 of E11-16: Ac and E11-16-OH attracts significantly greater number of male moths (Cork *et al*., 2001).

Considering the importance of BSFB for the production of brinjal it is necessary to explore the environment friendly management practices for controlling BSFB. Under the above circumstances the present study was undertaken with the following objectives-

- To find out the effectiveness of different trap type on BSFB catch
- To identify the effectiveness of different trap height on BSFB catch
- To develop an eco-friendly approach for the management of BSFB by a combination of mass trapping and crop hygiene practice.

CHAPTER II

REVIEW OF LITERATURE

Brinjal is one of the most important vegetable crop in Bangladesh and many countries of the world as well. Brinjal shoot and fruit borer (BSFB) is the most destructive pest of brinjal. For controlling BSFB it is necessary to have a concept of the origin and distribution, pest status and host range, nature of damage, seasonal abundance and bionomics of the pest. Farmers mainly control BSFB through the use of different chemicals but the concept of management of pest employing eco-friendly materials gained momentum as mankind became more safely about environment. Among the different eco-friendly techniques, use of sex pheromone is the recent and important approach for pest control. But the information related to management of BSFB using sex pheromone is very scanty in our country context. Nevertheless, some of the informative and important and informative works and research findings related to the origin, distribution, pest status, host range, nature of damage, seasonal abundance, bionomics and control of BSFB through sex pheromone so far been done at home and abroad have been reviewed in this chapter under the following sub-headings-

2.1 Nomenclature

Kingdom: Animalia

Phylum: Arhropoda

Class: Insecta

Order: Lepidoptera

Family: Crambidae (Syn: Pyralidae)

Genus: *Leucinodes*

Species*: L. orbonalis*

Scientific name: *Leucinodes orbonalis*

2.2 Origin and distribution of BSFB

According to Butani and Jotwani (1984), *L. orbonalis*, the most destructive pest of eggplant is widely distributed not only in the Indian sub-continent but also in South Africa, Congo and Malaysia. Eggplants are severely attacked by shoot and fruit borer in the tropics but not in the temperate zone. Eggplant is a native of India and is extensively grown in all the Southeast Asian countries. It was introduced into Spain from India during the Moorish invasion from where it spread throughout the European counties then into America. The domesticated non- bitter types spread eastward into China by the fifth century BC from India (Yamaguchi, 1983).

The pest is reported from regions of eggplant cultivation in Africa, South of the Sahara and South-East Asia, including China and the Philippines. In Asia, it is the most important and the first ranked pest of India, Pakistan, Srilanka, Nepal, Bangladesh, Thailand, Philippines, Cambodia, Laos and Vietnam (AVRDC, 1994). Its distribution is mostly higher in those areas having hot and humid climate (Srinivasan, 2009).

2.3 Pest status and host range of BSFB

BSFB (*L. orbonalis*) is an endemic pest of eggplant in South Asia. It is practical lymonophagous, feeding principally on eggplant; however, other plants belonging to family Solanaceae are reported to be hosts of this pest. In the area of global eggplant cultivation, *L. orbonalis* also occurs on different host plants. Major recorded are: *Solanum melongena* Linnaeus (eggplant), *Solanum tuberosum* Linnaeus (potato) but there are several minor host, like *Ipomoea batatas* Linnaeus (sweet potato), *Lycopersicon esculentum* Mill (tomato), *Pisum sativum* var. *arvense* Linnaeus (Austrian winter pea) *Solanum indicum* Linnaeus, *Solanum myriacanthum* Dunal, *Solanumtorvum* Swartz (turkey berry) and wild host *Solanumgilo* Raddi (gilo), *Solanum nigrum* Linnaeus (black nightshade). In addition, *Solanum anomalum* Thonn (Singh and Kalda, 1997) and *Solanum macrocarpon* Linnaeus (Kumar and Sadashiva, 1996) are wild hosts of *L. orbonalis.* However, growth and development of BSFB on these plants is very slow. Given a choice, BSFB prefers eggplant to other hosts. Therefore, denying ESFB moths easy access to eggplant plants to lay their eggs upon is the first and surest way of controlling this pest.

2.4 Seasonal abundance

The seasonal history of BSFB varies considerably with varying climatic conditions throughout the year. Hibernation does not take place and the insects are found to be active in summer, especially in rainy season but less active during February to April (Alam, 1969). In winter months, the duration of different stages, last for longer periods. Overlapping of generations was observed. The population of *Leucinodes orbonalis* began to increase from the first week of July and peaked (50 larvae per 2 m rows) during the third week of August. The population of the pest was found to be positively correlated with average temperature, mean relative humidity and total rainfall (Shukla, 1989). There are altogether five generations of the pest in a year of which three of them occur during may to October and two from November to April. During summer each generation covers about four to six weeks but in winter it covers up to sixteen weeks (Alam, 1969).

There is a considerable mortality of larvae by rot caused by fungus during winter and by predatory black ants, *Camponotus compressus* F. during summer. Pupal mortality has been observed during rainy season due to attack of *Ichneumonid* parasitoid. The adult moths are also attacked by the black ant, *Camponotus compressus* F (Alam, 1969). Populations of *Leucinodes orbonalis* on eggplant increased in the 1st and 3rd and declined in the 2nd and 4th generations. Patel *et al.* (1988) observed low population variation in minimum and maximum temperatures but high relative humidity and heavy rain enhanced the population of this pest.

Pawar *et al*. (1986) found in India that the infestation of shoot began 30 days after transplantation with peaked in the second week of September and declined on the 1st week of November. The fruit infestation began 3rd week of September with a peek in the 2nd week of November. In summer, shoot infestation began 3rd week of January and the infestation reached a peak in then2nd week of February while fruit infestation peaked in the 1st week of April.

2.5 Life cycle of BSFB

Like other members of the order Lepidoptera, *L. orbonalis* goes through four growth stages: egg, larva, pupa and adult. The larval period is the longest, followed by pupal and incubation period.

Egg: Oviposition takes place during the night and eggs are laid singly on the lower surface of the young leaves, green stems, flower buds, or calyces of the fruits. And number of eggs laid by a female varies from 80 to 253 (Taley *et al.,* 1984; Alpuerto, 1994), however, reported as high as 260 (FAO, 2003). The eggs are laid in the early hours of the mornings singly or in the batches on the ventral surface of the leaves. They are flattened, elliptical with 0.5 mm in diameter and colour is creamy-white but change to red before hatching (Alam *et al.,* 2006). The egg takes incubation period of 3-5 days in summer and 7-8 days in winter and hatched into dark white larvae (Rahman, 2006).

Larva: The larval period lasts 12-15 days during summer and 14-22 days during winter season (Rahman *et al.,* 2006). Larvae pass through at least five instars (Atwal, 1976) and there are reports of the existence of six larval instars (Baang and Corey, 1991; FAO, 2003). Sandanayake and Edirisinghe (1992) studied the larval distribution on mature eggplant. They found first instars in flower buds and flowers, second instars in all susceptible plant parts, third and fourth instars in shoots and fruits and fifth instars mostly in fruits. In general, the size of the first instar larvae are less than 1mm in length, the last instar larva is 15-18 mm long but Sandanayeke and Edirinsinge (1992) reported the size of last instar larva to be 18 to 23 mm. Larval feeding in fruit and shoot is responsible for the damage to eggplant crop.

Pupa: The full-grown larvae come out of the infested shoots and fruits and for pupate in the dried shoots and leaves or in plant debris fallen on the ground within tough silken cocoons. There were evidences of presence of cocoons at soil depths of 1 to 3 cm (Alam *et al.,* 2003). They pupate on the surface they touch first (FAO, 2003). The pupal period lasts 6 to 17 days depending upon temperature (Alam *et al.,* 2003). It is 7-10 days during summer, while it is 13-15 days during winter season (Rahman, 2006). The color and texture of the cocoon matches the surroundings making it difficult to detect.

Adult: The adult is a small white moth with 40-segmented antennae (Sexena, 1965) and having spots on forewings of 20 to 22 mm spread. Young adults are generally found on the lower leaf surfaces following emergence or hiding under the leaves within the plant canopy (Alam *et al.,* 2003). During day, they prefer to hide in nearby shady plots but at night all major activities, like feeding, mating and finding a place for egg-laying take place (FAO, 2003). Only dead adults can be found in an eggplant field. The adult gains full maturity in 10 to 14 days. Longevity of adults lasts 1.5 to 2.4 days for males and 2.0 to 3.9 days for females. The pre-oviposition and oviposition periods ranges from1.2 to 2.1 and 1.4 to 2.9 days, respectively (Mehto *et al.,* 1983). The adult male died after mating while the female moth died after laying eggs (Kar *et al.,* 1995). The overall life cycle completed in 22 to 55 days. There are five generations found in a year and is active throughout the year. FAO (2003) showed the effect of climatic conditions in the life cycle of the *L. orbonalis* in eggplant. *L. orbonalis*is active in summer, especially during the rainy season and less active from November to February. Peak populations are often reported in June-August. Development of the different stages of the insect takes longer during the winter months. *L. orbonalis* populations are reported to increase with average temperature, relative humidity and rainfall. As temperature increases and humidity decreases, fecundity increases and the duration of the life cycle decreases.

2.6 Nature of damage of BSFB

Eggplant is severely attacked by shoot and fruit borer during the rainy and summer season. *L. orbonalis* attacks mostly on flowering, fruiting and vegetative growing stage on fruits/pods, growing points and inflorescence. The losses due to its infestation are sometimes reported to be more than 90% (Kallo, 1988).The damage by this pests starts soon after transplanting of the crop and continues upto the last harvest of the fruit. The higher percent of the larvae found in fruits followed by shoots, flowers, flower buds and midrib of leaves (Alpuruto, 1994).

The eggs are laid singly and deposited on the ventral surface of the leaves, shoots, flower buds, petiole and occasionally on the fruit. Within one hour after hatching, larva bores into the nearest tender shoot, flower, or fruit. Soon after boring into shoots or fruits, they plug or clog the entrance hole (feeding tunnel) with excreta (Alam *et al.*, 2006). In young plants, caterpillars are reported to bore inside petioles and midribs of large leaves (Butani and Jotwani, 1984; Alpureto, 1994; AVRDC, 1998) thereby wilting, drop off and wither of the young shoots leading to delay on crop maturity, reduction on yield and yield parameter. Larval feeding inside the fruit results in destruction of fruit tissue. In severe cases, rotting is common (Neupane, 2001). At later stage of the plant growth, the larvae bore generally through the calyx and later into the flower buds and the fruits without leaving any visible sign of infestation and feed inside (Butani and Jotwani, 1984). The infested flower buds dry and shed. Larval feeding in flower is rare, if happen, failure to form fruit from damaged flowers (Alam *et al.*, 2006). When fruits are available they prefer to bore into the fruit. Infested fruits show exit holes along with excreta. When an infested fruit is cut open, dark excreta, moulds and sometime rotten portion is found. Often the infested fruits become unfit for human consumption and marketing. Damage to the fruits, particularly in autumn, is very severe and the whole crop can be destroyed (Atwal, 1976). *L. orbonalis* is active throughout the year at places having moderate climate but its activity is adversely affected by severe cold. The full grown larvae come out through the exit hole and drop on the ground for pupation in the soil or plant debris, the larvae feed on the pith tissues of infested fruit by boring tunnels. The percent infestation of fruit is more than that of shoots (Alam and Sana, 1962). The pest is reported to cause 1 to 16% damage to shoots and 16 to 64% damage to fruits (Butani and Jotwani, 1984). Hami (1955) found that vitamin C (ascorbic acid) is reduced to the extent of 68% in infested fruit. Peswani and Rattan (1964) reported that this borer damaged 20.7% fruits and if only damaged portion of these fruits is discarded, the loss in weight comes to 9.7%.

2.7 Sex pheromone based management of brinjal shoot and fruit borer

Pheromone is a term derived from the Greek words Pherein 'to transmit', Hormone 'to excite'. This term is used to define the substances secreted to the outside by an individual and perceived by a second individual of the same species. In which they release a specific behavioral reaction such as sexual, defensive, recognition among others (Karlson and Luscher, 1959).

Sex pheromones are important component of IPM programs mainly used to monitor as well as mass-trap the male insects. The IPM strategy based on sex pheromone for managing the *L. orbonalis* has reduced pesticide abuse and enhanced the activities of natural enemies in Indo-Gangetic plains of South Asia (Srinivasan, 2012). The sex pheromone confused the male adult for mating and thus preventing fertilized egg production by trapping significant number of male moths, which resulted reduction of larval and adult population build–up. Thus, this technology can be expanded as IPM technology may be beneficial in holistic manner (Mathur *et al.,* 2012).

Sex pheromone has been utilized in the insect pest control program through population survey and in behavioral manipulation. Due to the absence of its harmless effect on the environment it becomes popular as one of the pest management tools in IPM. Over 150 species of insects are known in which the females produces sex pheromone and about 50 in which the males do so. In another study it was reported that the sex pheromone have been detected from over 1000 species of insect and are commercially synthesized and readily available for the control of about 280 species of insect pests in the world. The virgin female of *L. orbonalis* is one of the sex pheromone producing insects and was demonstrated by Gunawardena *et al.* (1989). The compound has been used effectively for pest management as monitoring adult population, mating disruption and attacking and killing the target pests in the trap.

Zhu *et al*. (1987) identified (E)-11-hexadecenyl acetate (E11-16: Ac) as the major component of EFSB sex pheromone in China. They synthesized this chemical in the laboratory and used at the rate of 300-500 μg per trap to attract the EFSB males in the field. Attygalle *et al*. (1988) and Gunawardena *et al*. (1989) also identified the presence of this compound from the sex pheromone glands of EFSB in Sri Lanka. In addition, they have also identified trace quantities of (E)- 11-hexadecen-1-ol (E11-16: OH). E11-16: Ac was synthesized in the laboratory and tested for its attraction in Sri Lanka. Although it attracted male moths in the laboratory, its performance under field conditions was inferior to live virgin female moths (Gunawardena *et al*., 1989). However, E11-16: Ac when used alone or in combination with E11-16: OH attracted significantly high numbers of male moths in India and Bangladesh, although E11-16: OH alone showed no attraction at any concentration (AVRDC, 1996; Srinivasan and Babu, 2000). Cork *et al*. (2001) at the Natural Resources Institute (NRI), UK also identified the presence of E11-16: Ac as a major component and E11-16: OH as a minor component in the pheromone gland extracts of EFSB from India and Taiwan. They also found that E11-16: Ac and E11-16: OH (100:1) attracted significantly more numbers of male moths than E11-16: Ac alone in India.

Hence, the EFSB sex pheromone was included as a potential component in the EFSB IPM program that was implemented by AVRDC in South Asia. Delta traps and funnel traps could be used for the EFSB sex pheromone lures in field conditions. However, the trap design that would attract more numbers of insects will vary from one location to the other. Hence, it had to be confirmed in repeated field experiments. For instance, in the AVRDC-led EFSB IPM program in South Asia, delta IPM for Eggplant fruit and shoot borer 107 traps consistently caught more EFSB male moths than funnel traps in Gujarat, whereas funnel traps performed better than delta and water-trough traps in Uttar Pradesh (Alam *et al*., 2003). Similarly, delta traps caught and retained ten times more moths than either *Spodoptera* oruni-trap designs in Bangladesh (Cork *et al*., 2003).

The optimal trap height will also vary with locations. As an example, the traps placed at crop canopy level caught significantly more male moths than traps placed 0.5 m above or below the crop canopy in Bangladesh (Cork *et al*., 2003). Whereas, traps installed 0.25 m above crop canopy caught higher moths than either at crop canopy or at 0.25 m below crop canopy in Uttar Pradesh (Alam *et al*., 2003). The traps should be erected at every 10 m or less for effective attraction. In general, it has been suggested to place the traps at a density of 100 per ha (Cork *et al*., 2003). Thus, the EFSB sex pheromone traps as a component of IPM significantly reduced the fruit damage and increased the yield in South Asia (Alam *et al*., 2003; Cork *et al*., 2001).

In field trials conducted in India blends containing between 1 and 10% E11-16: OH caught significantly more male *L. orbonalis* than E11-16: Ac alone at 100 mg dose, addition of 1% E11-16: OH to E11-16: Ac was found to be significantly more attractive to male *L. orbonalis* than either 0.1 or 10% E11-16: OH. Trap catches was found to be positively correlated with pheromone release rate, with the highest dose tested, 3000 mg catching significantly more male moths than lower doses (Cork *et al*., 2001).

Replicated IPM trials were conducted in farmers fields in Jessore, Bangladesh, with brinjal crops farmers applied insecticides at least three times a week in both check and IPM plots. In addition, infested shoots were removed weekly and pheromone traps were placed out at a density of 100 per ha in the IPM plots (Cork *et al.*, 2003). Pheromone trap catches were reduced significantly from 2.0 to 0.4 moths per trap per night respectively in check and IPM plots in young crop and 1.1 to 0.3 moths per trap per night in check and IPM plots respectively in a mature crop. Fruit damage was significantly reduced from an average of 41.8% and 51.2% in check plots of young and mature crops and to 22% and 26.4%, respectively in the associated IPM tools. The relative impact of removing infested shoots and mass trapping on *L. orbonalis* larval populations was not established in these trials but in both cases there was an estimated increase of approximately 50% in marketable fruit obtained by the combination of control techniques compared to insecticide treatment alone (Cork *et al*., 2003).

Alam *et al.* (2003) conducted IPM trials at Jessore and Noakhali in Bangladesh during summer 2002. They compared the efficacy of IPM package consisting of sanitation i.e., prompt removal of pest-damaged shoots and fruits, trapping of male moths using sex pheromone and farmers BSFB management practices (insecticide spray at everyday or every alternative day). They portrayed that the shoot infestation as well as fruit infestation in the IPM trials was very much less than the farmer's field.

Two studies were conducted by Anonymous (2007) at the experimental field of Entomology Division, Bangladesh Agricultural Research Institute (BARI) on different trap designs and trap heights for effective trapping of BSFB. Among the three trap designs tested, Bangalore "open water trap" was the most effective in trapping BSFB moths, followed by BARI water trap and Indian funnel trap. Significantly higher number of BSFB moths were caught in the traps set below canopy level (0.5 m above ground) and at canopy level (1 m above ground) than that of above canopy level (1.5 m above ground level). Trap set below canopy level caught 5.44 times more BSFB male moths followed by traps set at canopy level (4.66 times) compared to those placed at upper canopy level.

Studies were undertaken at the experimental field of Entomology Division, Bangladesh Agricultural Research Institute (BARI) on different pheromone dispensers (Lures) and trap locations in the brinjal field to evaluate the efficiency of trapping BSFB male moths (Anonymous, 2007). Rubber septa lures of Agrol and Biotech Ltd. attracted and trapped significantly higher number of BSFB moths (15.55 moth/trap), while lure of NRI, UK secured the second position (9.58 moth/trap). Lures collected from Ganesh Bio-control and AgroSense attracted significantly less numbers of BSFB. Trap setting at edge of the brinjal field was the most effective. It trapped 1.8 times more BSFB moths than the traps set at the centre of the field.

Zhu *et al.* (1987) reported that the main component of the female sex pheromone of *L. orhonalis* which is a serious pest of eggplant in various regions of China, was identified as (li)-l 1-hexadecanyl acetate. It was synthesized in the laboratory and tested in the field where more males were captured in traps baited with 300-500 mg of the compound than by 6 live females.

Gunwardena *et al.* (1989) demonstrated that the virgin females of the brinjal shoot and fruit borer, *L. orbonalis*, secrete pheromone, which attracts male for mating. The compound has been effectively used for pest management and monitoring adult population, mating disruption and attacking and killing the target pest in the trap. Das and Islam (1984) reported that the field traps baited with virgin female moths of the brinjal shoot and fruit borer, *Leucinoodes orbonalis*, attracted both marked and wild males.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted to study the effect of pheromone traps and trapping locations on capturing of male moth of brinjal shoot and fruit borer and fruit yield of brinjal. The materials and methods were used for conducting the experiment have been presented in this chapter. It includes a short description of the location of experimental site, soil and climate conditions of the experimental area, materials used for the experiment, design of the experiment, data collection and data analysis procedure.

3.1 Description of the experimental site

3.1.1 Experimental period

The experiment was conducted during the period from November 2013 to April 2014.

3.1.2 Description of experimental site

The experiment was conducted at the research farm of Sher-e-Bangla Agricultural University (SAU), Dhaka. It was located in 24.09^0N latitude and 90.26^0E longitudes. The altitude of the location was 8 m above from the sea level as per the Bangladesh Metrological Department, Agargaon, Dhaka-1207.

3.1.3 Climatic conditions

The climate of experimental site is subtropical, characterized by three distinct seasons, the monsoon from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October.

The monthly average temperature, humidity and rainfall during the crop growing period were collected from Weather Yard, Bangladesh Meteorological Department, and presented in Appendix I. During the experimental period the maximum temperature (33.4^0C) was recorded from April, 2014 and the minimum temperature (12.4^0C) in the month of January, 2014. Highest relative humidity (78%) in the month of November, 2013 and the highest rainfall (78 mm) was recorded in the month of April 2014 and the highest sunshine hour (8.3) was recorded in the month of April, 2014.

3.1.4 Characteristics of soil

The soil of the experimental field belongs to the Tejgaon series under the Agroecological Zone, Madhupur Tract (AEZ- 28) and the general soil type is Shallow Red Brown Terrace soil. A composite sample was made by collecting soil from several spots of the field at a depth of 0-15 cm before the initiation of the experiment. The collected soil was air-dried, grind and passed through 2 mm sieve and analyzed at Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka for some important physical and chemical properties. The results have been presented in Appendix II.

3.2 Experimental details

3.2.1 Planting materials

Brinjal variety Shingnath was used as the test crop of this experiment. The seeds of Begun variety Shingnath were collected from Horticulture Research Centre, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur.

3.2.2 Treatments of the experiment

The experiment consisted of two factors:

Factor A: Pheromone traps (four type) as

i T_1: Funnel type trap

ii. T_2: GME trap

iii. T_3: BARI trap I

iv. T_4: BARI trap II

Factor B: Location of pheromone trap (two locations) as

i. L_1: Canopy level

ii. L_2: Upper canopy level

There were 8 (4 × 2) treatments combination such as T_1L_1, T_1L_2, T_2L_1, T_2L_2, T_3L_1, T_3L_2, T_4L_1 and T_4L_2.

3.2.3 Design and layout of the experiment

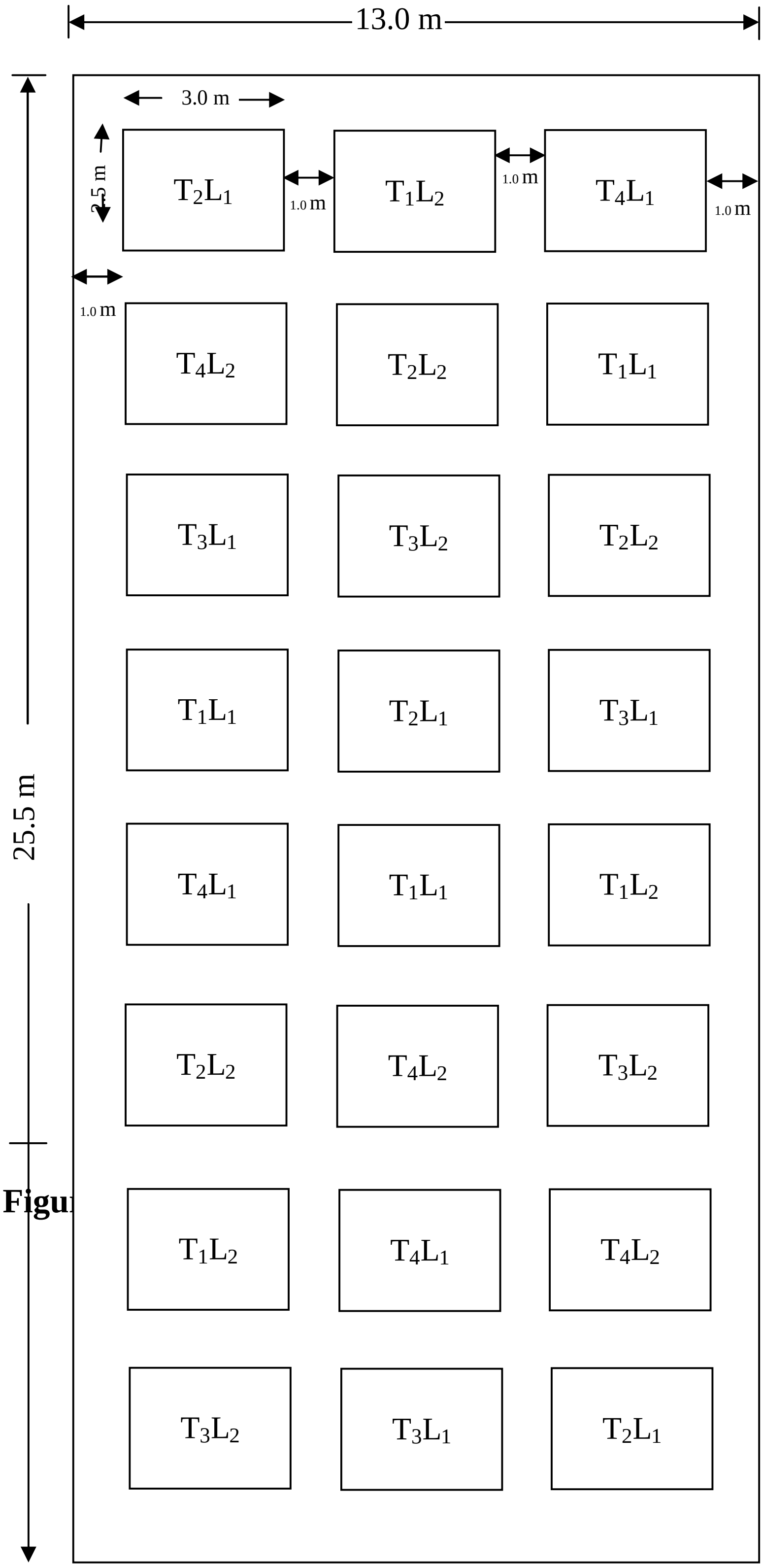
The two factorial experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The total area of the experimental plot was 331.5 m^2 with length 25.5 m and width 13.0 m. The total area was divided into three equal blocks. Each block was divided into 8 plots where 8 treatments combination were allotted at random. There were 24 unit plots and the size of each plot was 3.0 m × 2.5 m. The distance between blocks and plots was 1.0 m and 1.0 m, respectively. The layout of the experiment is shown in Figure 1.

3.2.4 Raising of seedlings

Brinjal seedlings were raised in seed beds of 3.0 m × 1.0 m size. The soil was well prepared and converted into loose friable and dried for seedbed. All weeds and stubbles were removed and well rotten cowdung was mixed with the soil. In each seed bed seeds were sown on 4th November 2013. After sowing, seeds were covered with light soil. Heptachlor 40 WP was applied @ 4 kg ha^{-1}, around each seedbed as precautionary measure against ants and worm. The emergence of the seedlings took place with 5 to 6 days after sowing. For healthy and uniform seedlings seed beds were watering when necessary and cleaned by removing weeds when emerged.

3.2.5 Land preparation

The plot selected for conducting the experiment was opened in the 2nd week of November 2013 with a power tiller, and left exposed to the sun for a week. After one week the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain until good tilth. Weeds and stubbles were removed, and finally obtained a desirable tilth of soil was obtained for transplanting brinjal seedlings. The experimental plot was partitioned into unit blocks and blocks into unit plots in accordance with the design mentioned in Figure 1. Cowdung and chemical fertilizers as indicated below in 3.3.5 were mixed with the soil of each unit plot.



N

W E

S

Plot size: 3.0 m × 2.0 m
Plot spacing: 1.0 m
Between block: 1.0 m

Factor A: Pheromone traps (four type) as

T_1: Funnel type trap

T_2: GME trap

T_3: BARI trap I

T_4: BARI trap II

Factor B: Location of pheromone trap (two locations) as

L_1: Canopy level

L_2: Upper canopy level

3.2.6 Application of manure and fertilizers

The sources of N, P_2O_5, K_2O and S as urea, TSP, MP and Zypsum were applied, respectively. The entire amounts of TSP and Zypsum were applied during the final land preparation. Urea was applied in basal and three equal installments at 15 days after transplanting, during fruiting stage and middle point of brinjal harvest with the amount was as per the mentioned below. MP was applied in basal at 15 days after transplanting and during fruiting stage with the amount was as per the mentioned below. Well-rotten cowdung 10 t/ha also applied during final land preparation. The following amount mentioned in Table 1 of manures and fertilizers were used which shown as tabular form recommended by BARI (2011).

Table 1. Fertilizers and manure applied for the experimental field

Manures and Fertilizers	Dose/ha	Application			
		Final land preparation	1st installment	2nd installment	3rd installment
Cowdung	10 tons	10 ton	--	--	--
Urea	375 kg	300 kg	25 kg	25 kg	25 kg
TSP	150 kg	150 kg	--	--	--
MP	250 kg	125 kg	50 kg	75 kg	--
Zypsum	100 kg	100 kg	--	--	--

3.2.7 Transplanting of seedlings

Healthy and uniform size of brinjal seedlings were uprooted separately from the seed bed and were transplanted in the experimental plots in the afternoon of 24th November, 2013 with maintaining 70 cm distance from row to row and 70 cm from plant to plant. This allowed an accommodation of 15 plants in each plot. The seed bed was watered before uprooting the seedlings from the seed bed so as to minimize damage to the roots. Seedlings were also planted around the border area of the experimental plots for gap filling.

3.2.8 Intercultural operations

After transplanting of seedlings, various intercultural operations such as irrigation (as per treatment), weeding and top dressing etc. were accomplished for better growth and development of the brinjal seedlings.

3.2.8.1 Irrigation and drainage

Over-head irrigation was provided with a watering can to the plots as per necessary. Excess water was effectively drained out at the time of heavy rain.

3.2.8.2 Stacking

When the plants were well established, stacking was done to each plant by bamboo sticks to keep them erect.

3.2.8.3 Weeding

Weeding was done to keep the plots clean and easy aeration of soil which ultimately ensured better growth and development. The newly emerged weeds were uprooted carefully as per necessary.

3.2.8.4 Top dressing

Urea and MP was used as top-dressed as mentioned in Table 1. The fertilizers were applied on both sides of plant rows and mixed well with the soil. Earthing up operation was done immediately after top-dressing with fertilizer.

3.2.9 Pheromone trap optimization

Four different types of traps, viz., funnel trap, GME trap and BARI trap I and Bari trap II, were evaluated in this experiment. Funnel type trap at canopy level and upper canopy level is presented in Plate 1. GME pheromone water trap was collected from Safe Agro Limited (Plate 2). Funnel type pheromone trap was made up of a plastic bottle with its both sides had two funnel. Lure was hanged inside the plastic bottle. Pheromone traps which are known as BARI trap I (Plate 3) and BARI trap II (Plate 4) was locally made with plastic jar having “v” shaped cut on two opposite side of the jar. These traps were 3 litter capacity, 22 cm tall. BARI trap I is rectangular clear plastic container and BARI trap II is bucket like plastic container. The ‘V’ shaped hole was 3 cm above the bottom. Water containing two to three drops of detergent should be maintained inside the traps throughout the season. (E)-11-hexadecenyl acetate (E11-16: Ac) was the major component of the female sex pheromone of brinjal shoot and fruit borer used in different types of traps. Pheromone soaked cotton or lure was tied inside the trap with thin wire. BSFB adult enter the trap and fall into the water and die. Water inside the trap should be replenished often to make sure the trap is not dry. Pheromone dispensers should be continued throughout the cropping season.

3.3 Crop sampling and data collection

Five plants from each treatment were randomly marked inside the central row of each plot with the help of sample card.

3.4 Monitoring and data collection

The brinjal plants of different treatment were closely examined at regular intervals commencing from germination to harvest. The following data were collected during the course of the experiment-

- Number of healthy shoots
- Number of infested shoots
- Percent shoot infestation in number
- Number of healthy fruits
- Number of infested fruits
- Percent fruit infestation in number
- Weight (g) of healthy fruits
- Weight (g) of infested fruit
- Fruit infestation in weight (%)
- Plant height at harvest (cm)
- Individual fruits weight (g)
- Fruit yield per hectare (ton)

3.4.1 Determination of shoot damage

All the healthy and infested shoots were counted from 5 randomly selected plants from middle rows of each plot and examined. The collected data were divided into early, mid and late fruiting stage according to harvest time. The healthy and damaged shoots were counted and the percent shoot damage was calculated using the following formula:

$$\text{Shoot infestation (\%)} = \frac{\text{Number of damaged shoot}}{\text{Total number of shoot}} \times 100$$

3.4.2 Determination of fruit infestation in number

All the healthy and infested fruits were counted from 5 randomly selected plants from middle rows of each plot and examined. The collected data were divided into early, mid and late fruiting stage. The healthy and infested fruits were counted and the percent fruit damage was calculated using the following formula:

$$\text{Fruit infestation (\%)} = \frac{\text{Number of infested fruits}}{\text{Total number of fruits}} \times 100$$

3.4.3 Determination of fruit infestation in weight

All the healthy and infested fruits were weighted from 5 randomly selected plants from middle rows of each plot and examined. The collected data were divided into early, mid and late fruiting stage. The healthy and infested fruits were weighted and the percent fruit infestation was calculated using the following formula:

$$\text{Fruit infestation (\%)} = \frac{\text{Weight of infested fruit}}{\text{Total weight of fruit}} \times 100$$

3.5 Harvest and post harvest operations

Harvesting of fruit was done when the fruits attained marketable sized**.** The optimum marketable sized fruits were collected by hand picking from each plot and yield was converted into t/ha.

3.6 Procedure of data collection

3.6.1 Plant height at harvest

The plant heights of 5 randomly selected plants were measured with a meter scale from the ground level to the top of the plants and the mean height was expressed in centimeter (cm). Data were recorded from the inner rows plant of each plot during harvesting period.

3.6.2 Individual fruit weight

Healthy fruits were collected from the ten randomly selected plants and were weighted by a digital electronic balance. The weight was expressed plant^{-1} basis in gram (g).

3.6.3 Fruits yield per hectare

Fruits per plot were converted into hectare and the weight of fruits per hectare was calculated and expressed in ton.

3.7 Statistical analyses

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

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to study the effect of pheromone traps and trapping locations on capturing male moth of brinjal shoot and fruit borer (BSFB) and its impact on shoot and fruit infestation of brinjal. The results have been presented by using different tables and graphs and discussed with possible interpretations under the following headings and sub headings:

4.1 Effect of pheromone traps on capturing male BSFB moth

Number of BSFB caught per trap per day showed statistically significant variation due to different types of pheromone traps (Figure 2). It was observed that the highest number of male BSFB moth (6.43) was caught in T_2 (GME trap) followed 5.73 and 5.52 in T_4 (BARI trap II) and T_3 (BARI trap I) respectively. On the other hand the lowest number of BSFB male moth (4.66) was caught in T_1 (Funnel type trap). Similarly, location of pheromone traps varied significantly in terms of number of BSFB caught per trap per day (Figure 3). The highest number of catch male BSFB (5.24) was found from L_1 (Canopy level) and the lowest number (3.69) from L_2 (Upper canopy level). Combined effect of different types of pheromone traps and location of pheromone traps showed statistically significant variation in terms of number of BSFB caught per trap per day (Figure 4). The highest number of catch male BSFB (7.34) was recorded from T_2L_1 (GME trap located at canopy level).

This result agreed with the findings of Rahman *et al.* (2009) who reported that the sex pheromone confused the male adult for mating and thus preventing fertilized egg production by trapping significant number of male moths. It also agreed with report of Cork *et al.* (2003) who observed that the traps placed at crop canopy level caught significantly more male moths than placed 0.5 m above the canopy.

4.2 Effect of pheromone traps on shoots infestation by BSFB

Number of healthy and infested shoots per plant and intensity of shoot infestation of brinjal plant was recorded at early, mid and late fruiting stage and statistically significant variation was found for different types of pheromone trap.

4.2.1 Early fruiting stage

At early fruiting stage, number of healthy and infested shoots per plant and shoot infestation varied significantly due to different types of pheromone traps (Table 2). The highest number of healthy shoots per plant was found in T_2 (23.23) followed by T_4 (21.77) and T_3 (20.47), while the lowest number (20.27) was recorded in T_1. The lowest number of infested shoots per plant was recorded in T_2 followed by T_4 (1.67) and T_3 (1.87), while the highest number was recorded in T_1 (2.07). The lowest shoot infestation was found in T_2 (5.21%) followed by T_4 (7.19%) and T_3 (8.40%), while the highest shoot infestation was recorded in T_1 (9.40%).

Location of pheromone traps varied significantly in terms of number of healthy and infested shoots per plant and shoot infestation at early fruiting stage (Table 2). The highest number of healthy shoots per plant was found in L_1 (21.79) and the lowest number was recorded in L_2 (18.69). The lowest number of infested shoots per plant was observed in L_1 (1.83) while the highest number was recorded in L_2 (2.08). The lowest shoot infestation was found in L_1 (8.07%) and the highest shoot infestation was recorded in L_2 (10.37%).

Combined effect of different types of pheromone traps and location of pheromone traps showed statistically significant variation in terms of number of healthy and infested shoots per plant and shoot infestation at early fruiting stage (Table 3). The highest number of healthy shoots per plant was found in T_2L_1 (24.60) and the lowest number was recorded in T_1L_2 (17.60). The lowest number of infested shoots per plant was found in T_2L_1 (1.13) but the highest number was recorded in T_1L_2 (2.12). The lowest shoot infestation was found in T_2L_1 (4.40%) having significant difference with other treatment combinations. On the other hand the highest shoot infestation was recorded in T_1L_2 (10.53%) which was significantly higher than all other treatment combinations.

Table 2. Effect of pheromone traps and trapping locations on shoot infestation caused by BSFB

Treatments	Brinjal shoot per plant								
	Early fruiting stage			Mid fruiting stage			Late fruiting stage		
	Healthy (No.)	Infested (No.)	Infestation (%)	Healthy (No.)	Infested (No.)	Infestation (%)	Healthy (No.)	Infested (No.)	Infestation (%)
Pheromone traps									
T_1	20.27 c	2.07 a	9.40 a	22.40 d	3.57 a	13.78 a	26.93 c	4.70 a	14.89 a
T_2	23.23 a	1.27 d	5.21 d	31.90 a	1.97 d	5.82 d	33.40 a	2.40 d	6.73 d
T_3	20.47 c	1.87 b	8.40 b	27.00 c	3.30 b	10.91 b	29.30 b	4.00 b	12.03 b
T_4	21.77 b	1.67 c	7.19 c	29.50 b	2.70 c	8.44 c	30.97 b	3.20 c	9.38 c
$LSD_{(0.05)}$	**1.19**	**0.13**	**0.78**	**1.56**	**0.24**	**0.86**	**2.15**	**0.28**	**0.46**
Level of significance	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**
Trapping locations									
L_1	21.79 a	1.83 b	8.07 b	27.76 a	3.23 b	10.78 b	29.79 a	3.92 b	11.94 b
L_2	18.69 b	2.08 a	10.37 a	25.68 b	3.47 a	12.23 a	27.81 b	4.40 a	13.98 a
$LSD_{(0.05)}$	**0.76**	**0.08**	**0.49**	**0.99**	**0.15**	**0.55**	**1.36**	**0.18**	**0.29**
Level of significance	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**
CV (%)	**4.86**	**5.32**	**6.93**	**4.82**	**5.80**	**6.19**	**6.14**	**5.55**	**4.90**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability by DMRT

T_1: Funnel type trap T_2: GME trap
T_3: BARI trap I T_4: BARI trap II

L_1: Canopy level L_2: Upper canopy level

Table 3. Combined effect of pheromone traps and trapping locations on brinjal shoot infestation caused by BSFB

Treatments	Brinjal shoot per plant								
	Early fruiting stage			Mid fruiting stage			Late fruiting stage		
	Healthy (No.)	Infested (No.)	Infestation (%)	Healthy (No.)	Infested (No.)	Infestation (%)	Healthy (No.)	Infested (No.)	Infestation (%)
T_1L_1	22.93 abc	2.07 a	8.28 bc	23.60 d	3.53 ab	13.03 b	28.07 cd	4.40 b	13.55 b
T_1L_2	17.60 f	2.12 a	10.53 a	21.20 e	3.60 a	14.54 a	25.80 de	5.00 a	16.24 a
T_2L_1	24.60 a	1.13 e	4.40 e	33.20 a	1.80 e	5.13 f	34.60 a	2.20 g	5.97 h
T_2L_2	21.87 bc	1.40 d	6.02 d	30.60 b	2.13 e	6.52 e	32.20 ab	2.60 f	7.48 g
T_3L_1	21.53 cd	1.73 bc	7.45 c	27.80 c	3.20 bc	10.32 cd	30.20 bc	3.80 c	11.18 d
T_3L_2	19.40 e	2.00 ab	9.36 b	26.20 c	3.40 ab	11.50 c	28.40 cd	4.20 b	12.88 c
T_4L_1	23.47 ab	1.47 d	5.88 d	30.80 b	2.53 d	7.64 e	31.87 ab	3.00 e	8.61 f
T_4L_2	20.07 de	1.87 bc	8.51 bc	28.20 c	2.87 cd	9.24 d	30.07 bc	3.40 d	10.16 e
$LSD_{(0.05)}$	**1.69**	**0.18**	**1.10**	**2.21**	**0.33**	**1.22**	**3.04**	**0.40**	**0.64**
Level of significance	**0.05**	**0.05**	**0.05**	**0.05**	**0.01**	**0.05**	**0.05**	**0.05**	**0.01**
CV (%)	**4.86**	**5.32**	**6.93**	**4.82**	**5.80**	**6.19**	**6.14**	**5.55**	**4.90**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability by DMRT

T_1: Funnel type trap T_2: GME trap

T_3: BARI trap I T_4: BARI trap II

L_1: Canopy level L_2: Upper canopy level

4.2.2 Mid fruiting stage

At mid fruiting stage, number of healthy and infested shoots per plant and percent shoot infestation varied significantly due to different types of pheromone traps (Table 2). The highest number of healthy shoots per plant was found in T_2 (31.90) followed by T_4 (29.50) and T_3 (27.00), while the lowest number was recorded in T_1 (22.40). The lowest number of infested shoots per plant was observed in T_2 (1.97) followed by T_4 (2.70) and T_3 (3.30), while the highest number was recorded in T_1 (3.57). The lowest shoot infestation was found in T_2 (5.82%) which was followed by T_4 (8.44%) and T_3 (10.91%), while the highest shoot infestation was recorded in T_1 (13.78%).

Location of pheromone traps varied significantly in terms of number of healthy and infested shoots per plant and shoot infestation at mid fruiting stage (Table 2). The highest number of healthy shoots per plant was experienced in L_1 (27.76) while the lowest number was recorded in L_2 (25.68). The lowest number of infested shoots per plant was found in L_1 (3.23) but the highest number was recorded in L_2 (3.47). The lowest shoot infestation was found in L_1 (10.78%) whereas the highest shoot infestation was recorded in L_2 (12.23%).

Combined effect of different types of pheromone traps and location of pheromone traps showed statistically significant variation in terms of number of healthy and infested shoots per plant and shoot infestation at mid fruiting stage (Table 3). The highest number of healthy shoots per plant was found in T_2L_1 (33.30) but the lowest number was recorded in T_1L_2 (21.20). The lowest number of infested shoots per plant was found in T_2L_1 (1.80) while the highest number was recorded in T_1L_2 (3.60). The lowest shoot infestation was found in T_2L_1 (5.13%) that was significantly lower than all other treatment combinations. In contrast the highest shoot infestation was recorded in T_1L_2 (14.54%) having significant different with other treatment combinations.

4.2.3 Late fruiting stage

At late fruiting stage, number of healthy and infested shoots per plant and shoot infestation varied significantly due to different types of pheromone traps (Table 2). The highest number of healthy shoots per plant was observed in T_2 (33.40) followed by T_4 (30.97) and T_3 (29.30), while the lowest number was recorded in T_1 (26.93). On the other hand, the lowest number of infested shoots per plant was found in T_2 (2.40) followed by T_4 (3.20) and T_3 (4.00), while the highest number was recorded in T_1 (4.70). The lowest shoot infestation was found in T_2 (6.73%) followed by T_4 (9.38%) and T_3 (12.03%), while the highest shoot infestation was recorded in T_1 (14.89%).

Location of pheromone traps varied significantly in terms of number of healthy and infested shoots per plant and shoot infestation at late fruiting stage (Table 2). The highest number of healthy shoots per plant was observed in L_1 (29.79) and the lowest number was recorded in L_2 (27.81). The lowest number of infested shoots per plant was found in L_1 (3.92) and the highest number was recorded in L_2 (4.40). The lowest shoot infestation was found in L_1 (11.94%) and the highest shoot infestation was recorded in L_2 (13.98%).

Combined effect of different types of pheromone traps and location of pheromone traps showed statistically significant variation in terms of number of healthy and infested shoots per plant and shoot infestation at late fruiting stage (Table 3). The highest number of healthy shoots per plant was observed in T_2L_1 (34.60) but the lowest number was recorded T_1L_2 (25.80). The lowest number of infested shoots per plant was found in T_2L_1 (2.20) while the highest number was recorded T_1L_2 (5.00). The lowest shoot infestation was found in T_2L_1 (5.97%) having significant difference with other treatments. On the other hand the highest shoot infestation was recorded T_1L_2 (16.24%) which was significantly different from other treatment combinations.

The results regarding shoot infestation of brinjal by shoot and fruit borer indicate that highest number of healthy shoot, lowest number of infested shoot and lowest percentage of shoot infestation was found in T_2L_1 (GME pheromone trap located at canopy level). In contrast the lowest number of healthy shoot, highest number of infested shoot and highest percentage of shoot infestation was observed in T_1L_2 (Funnel type pheromone trap located at upper canopy level). This result agreed with report of Cork *et al*. (2003) who observed that the traps placed at crop canopy level caught significantly more male moths than placed 0.5 m above the canopy. Thus GME type pheromone traps located at canopy level caught more adult male moths and reduced shoot infestation of brinjal at different stages of crop growth.

4.3 Effect of pheromone traps on fruit infestation by BSFB

Number of healthy and infested fruits per plant and intensity of fruit infestation was recorded at early, mid and late fruiting stage and statistically significant variation was found for different types of pheromone trap.

4.3.1 Early fruiting stage

At early fruiting stage, number of healthy and infested fruits per plant and fruit infestation varied significantly due to different types of pheromone trap (Table 4). The highest number of healthy fruits per plant was found in T_2 (14.90) which statistically similar to T_4 (14.23) and T_3 (13.87), while the lowest number was recorded in T_1 (12.27). The lowest number of infested fruits per plant was found in T_2 (0.70) followed by T_4 (1.17) and T_3 (1.50), while the highest number was recorded in and also T_1 (1.77). The lowest fruit infestation was found in T_2 (4.52%) followed by T_4 (7.68%) and T_3 (9.82%), while the highest fruit infestation was recorded in T_1 (12.65%).

Location of pheromone traps varied significantly in terms of number of healthy and infested fruits per plant and fruit infestation at early fruiting stage (Table 4). The highest number of healthy fruits per plant was observed in L_1 (14.04) and the lowest number was recorded in L_2 (12.51). The lowest number of infested fruits per plant was found in L_1 (1.43) and the highest number was recorded in L_2 (1.56). The lowest fruit infestation was found in L_1 (9.44%) whereas the highest fruit infestation was recorded in L_2 (11.40%).

Combined effect of different types of pheromone traps and location of pheromone traps showed statistically significant variation in terms of number of healthy and infested fruits per plant and fruit infestation at early fruiting stage (Table 5). The highest number of healthy fruits per plant was found in T_2L_1 (15.27) but the lowest number was recorded in T_1L_2 (11.40). The lowest number of infested fruits per plant was found in T_2L_1 (0.60) but the highest number was recorded T_1L_2 (1.80). The lowest fruit infestation was found in T_2L_1 (3.80%) having significant difference with other treatments. In contrast the highest fruit infestation was recorded from T_1L_2 (13.64%) which was significantly different from other treatment combinations.

4.3.2 Mid fruiting stage

At mid fruiting stage, number of healthy and infested fruits per plant and fruit infestation varied significantly due to different types of pheromone trap (Table 4). The highest number of healthy fruits per plant was found in T_2 (17.50) which was statistically similar to T_4 (16.60) followed by T_3 (15.60), while the lowest number was recorded in T_1 (15.10). The lowest number of infested fruits per plant was found in T_2 (1.10) followed by T_4 (1.80) and then T_3 (2.07), while the highest number was recorded in T_1 (2.93). The lowest fruit infestation was found in T_2 (5.92%) which was followed by T_4 (9.78%) and T_3 (11.74%), while the highest fruit infestation was recorded in T_1 (15.07%).

Table 4. Effect of pheromone traps and trapping locations on brinjal fruit infestation caused by BSFB

Treatments	Brinjal fruit per plant (number basis)								
	Early fruiting stage			Mid fruiting stage			Late fruiting stage		
	Healthy (No.)	Infested (No.)	Infestation (%)	Healthy (No.)	Infested (No.)	Infestation (%)	Healthy (No.)	Infested (No.)	Infestation (%)
Pheromone trap types									
T_1	12.27 b	1.77 a	12.65 a	15.10 c	2.67 a	15.07 a	12.00 c	2.67 a	18.21 a
T_2	14.90 a	0.70 d	4.52 d	17.50 a	1.10 d	5.92 d	14.00 a	1.00 d	6.69 d
T_3	13.87 a	1.50 b	9.82 b	15.60 bc	2.07 b	11.74 b	12.70 b	2.20 b	14.77 b
T_4	14.23 a	1.17 c	7.68 c	16.60 ab	1.80 c	9.78 c	13.40 a	1.90 c	12.42 d
$LSD_{(0.05)}$	**1.08**	**0.14**	**1.04**	**1.36**	**0.23**	**1.63**	**0.65**	**0.18**	**1.26**
Level of significance	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**
Trapping locations									
L_1	14.04 a	1.43 b	9.44 b	16.56 a	2.01 b	11.81 b	12.73 a	2.07 b	14.13 b
L_2	12.51 b	1.56 a	11.40 a	15.04 b	2.21 a	13.23 a	12.31 b	2.25 a	15.68 a
$LSD_{(0.05)}$	**0.68**	**0.09**	**0.66**	**0.87**	**0.15**	**1.03**	**0.41**	**0.11**	**0.11**
Level of significance	**0.01**	**0.01**	**0.01**	**0.05**	**0.01**	**0.01**	**0.05**	**0.01**	**0.01**
CV (%)	**6.69**	**7.56**	**8.22**	**7.30**	**9.09**	**10.72**	**4.30**	**6.83**	**6.97**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability by DMRT

T_1: Funnel type trap T_2: GME trap
T_3: BARI trap I T_4: BARI trap II

L_1: Canopy level L_2: Upper canopy level

Table 5. Combined effect of pheromone traps and trapping locations on brinjal fruit infestation caused by BSFB

Treatments	Brinjal fruit per plant (number basis)								
	Early fruiting stage			Mid fruiting stage			Late fruiting stage		
	Healthy (No.)	Infested (No.)	Infestation (%)	Healthy (No.)	Infested (No.)	Infestation (%)	Healthy (No.)	Infested (No.)	Infestation (%)
T_1L_1	13.13 bcd	1.73 a	11.66 b	15.40 bc	2.60 a	14.51ab	12.27 de	2.60 a	17.52 b
T_1L_2	11.40 e	1.80 a	13.64 c	14.80 c	2.73 a	15.62 a	11.73 e	2.73 a	18.89 a
T_2L_1	15.27 a	0.60 e	3.80 e	17.60 a	0.93 d	5.04 f	14.20 a	0.80 e	5.41 h
T_2L_2	14.53 abc	0.80 d	5.24 e	17.40 ab	1.27 c	6.79 ef	13.80 ab	1.20 d	7.98 g
T_3L_1	14.73 ab	1.40 b	8.68 c	16.00 abc	2.00 b	11.11 cd	12.80 bcd	2.07 c	13.91 d
T_3L_2	13.00 cd	1.60 a	10.96 a	15.20 c	2.13 b	12.37 bc	12.60 cde	2.33 b	15.62 c
T_4L_1	15.27 a	1.13 c	6.94 d	16.80 abc	1.67 b	9.03 de	13.60 abc	1.87 c	12.07 f
T_4L_2	13.20 bcd	1.20 c	8.42 c	16.40 abc	1.93 b	10.53 cd	13.20 abcd	1.93 c	12.78 e
$LSD_{(0.05)}$	**0.51**	**0.20**	**1.47**	**1.92**	**0.33**	**2.30**	**0.92**	**0.25**	**0.25**
Level of significance	**0.05**	**0.01**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**
CV (%)	**6.69**	**7.56**	**8.22**	**7.30**	**9.09**	**10.72**	**4.30**	**6.83**	**6.97**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

T_1: Funnel type trap　　T_2: GME trap

T_3: BARI trap I　　T_4: BARI trap II

L_1: Canopy level　　L_2: Upper canopy level

Location of pheromone traps varied significantly in terms of number of healthy and infested fruits per plant and fruit infestation at mid fruiting stage (Table 4). The highest number of healthy fruits per plant was found in L_1 (16.56) but the lowest number was recorded in L_2 (15.04). On the other hand, the lowest number of infested fruits per plant was found in L_1 (2.01) while the highest number was recorded in L_2 (2.21). The lowest fruit infestation was found in L_1 (11.81%) and the highest fruit infestation was recorded in L_2 (13.23%).

In case of combined effects of different types of pheromone traps and location of pheromone traps showed statistically significant variation in terms of number of healthy and infested fruits per plant and fruit infestation at mid fruiting stage (Table 5). The highest number of healthy fruits per plant was found in T_2L_1 (17.60) and the lowest number was recorded T_1L_2 (14.80). The lowest number of infested fruits per plant was found in T_2L_1 (0.93) but the highest number was recorded T_1L_2 (2.73). The lowest fruit infestation was found in T_2L_1 (5.04%) and the highest was recorded T_1L_2 (15.62%).

4.3.3 Late fruiting stage

At late fruiting stage, number of healthy and infested fruits per plant and fruit infestation varied significantly due to different types of pheromone trap (Table 4). The highest number of healthy fruits per plant was found in T_2 (14.00) which was statistically similar to T_4 (13.40) followed by T_3 (12.70), while the lowest number was recorded in T_1 (12.00). The lowest number of infested fruits per plant was found in T_2 (1.00) followed by T_4 (1.90) and T_3 (2.20), while the highest number was recorded in T_1 (2.67). The lowest fruit infestation was found in T_2 (6.69%) followed by T_4 (12.42%) and T_3 (14.77%) while the highest in T_1 (18.21%).

Location of pheromone traps varied significantly in terms of number of healthy and infested fruits per plant and fruit infestation at late fruiting stage (Table 4). The highest number of healthy fruits per plant was found in L_1 (12.73) but the lowest in L_2 (12.31). The lowest number of infested fruits per plant was observed in L_1 (2.07) while the highest in L_2 (2.25). The lowest fruit infestation was found in L_1 (14.13%) but the highest in L_2 (15.68%).

Combined effect of different types of pheromone traps and location of pheromone traps showed significant variation in terms of number of healthy and infested fruits per plant and fruit infestation at late fruiting stage (Table 5). The highest number of healthy fruits per plant was found in T_2L_1 (14.20) while the lowest number in T_1L_2 (11.73). The lowest number of infested fruits per plant was recorded in T_2L_1 (0.80) and the highest number in T_1L_2 (2.73). The lowest fruit infestation was found in T_2L_1 (5.41%) and the highest was recorded in T_1L_2 (18.89%).

4.4 Effect of pheromone traps on fruit infestation by BSFB in weight basis

Weight of healthy and infested fruits per plant and intensity of fruit infestation in weight basis was recorded at early, mid and late fruiting stage and statistically significant variation was found for different types of pheromone trap.

4.4.1 Early fruiting stage

At early fruiting stage, weight of healthy and infested fruits per plant and fruit infestation varied significantly due to different types of pheromone traps (Table 6). The highest weight of healthy fruits per plant was found in T_2 (707.72 g) followed by T_4 (675.76 g) and T_3 (635.46 g), while the lowest in T_1 (594.47 g). The lowest weight of infested fruits per plant was observed in T_2 (42.58 g) followed by T_4 (65.31 g) and T_3 (77.76 g), while the highest weight was recorded in T_1 (94.57 g). The lowest fruit infestation was found in T_2 (5.68%) followed by T_4 (8.82%) and T_3 (10.92%), while the highest in T_1 (13.73%).

Location of pheromone traps varied significantly in terms of weight of healthy and infested fruits per plant and fruit infestation at early fruiting stage (Table 6). The highest weight of healthy fruits per plant was found in L_1 (630.27 g) and the lowest in L_2 (614.87 g). The lowest weight of infested fruits per plant was recorded in L_1 (76.66 g) while the highest in L_2 (80.09 g). The lowest fruit infestation was found in L_1 (11.16%) but the highest in L_2 (11.81%).

Combined effect of different types of pheromone traps and location of pheromone traps showed statistically significant variation in terms of weight of healthy and infested fruits per plant and fruit infestation at early fruiting stage (Table 7). The highest weight of healthy fruits per plant was found in T_2L_1 (717.70 g) while the lowest in T_1L_2 (583.50 g). Quite the opposite, the lowest weight of infested fruits per plant was found in T_2L_1 (41.51 g) but the highest in T_1L_2 (93.60 g). The lowest fruit infestation was found in T_2L_1 (5.47 g) and the highest in T_1L_2 (13.84%).

Table 6. Effect of pheromone traps and trapping locations on brinjal fruit infestation in weight basis caused by BSFB

Treatments	Brinjal fruit per plant (weight basis)								
	Early fruiting stage			Mid fruiting stage			Late fruiting stage		
	Healthy (g)	Infested (g)	Infestation (%)	Healthy (g)	Infested (g)	Infestation (%)	Healthy (g)	Infested (g)	Infestation (%)
Pheromone trap types									
T_1	594.47 d	94.57 a	13.73 a	710.72 c	137.62 a	16.23 a	578.65 c	140.15 a	19.51 a
T_2	707.72 a	42.58 d	5.68 d	797.27 a	57.25 d	6.70 d	663.95 a	52.55 d	7.35 d
T_3	635.46 c	77.76 b	10.92 b	716.03 c	98.22 b	12.07 b	612.23 b	104.62 b	14.60 b
T_4	675.76 b	65.31 c	8.82 c	746.78 b	85.55 c	10.28 c	630.35 b	94.45 c	13.06 c
$LSD_{(0.05)}$	**24.15**	**3.02**	**0.60**	**21.66**	**4.12**	**0.40**	**22.31**	**3.36**	**0.71**
Level of significance	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**
Trapping locations									
L_1	630.27 a	76.66 b	11.16 b	732.45 a	108.19 b	12.90 b	612.26 a	106.48 b	14.96 b
L_2	614.87 b	80.09 a	11.81 a	713.08 b	112.55 a	13.70 a	586.07 b	112.74 a	16.23 a
$LSD_{(0.05)}$	**15.27**	**1.91**	**0.38**	**13.70**	**2.60**	**0.25**	**14.11**	**2.12**	**0.45**
Level of significance	**0.05**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**
CV (%)	**5.20**	**4.18**	**4.29**	**5.47**	**6.07**	**5.46**	**4.07**	**5.52**	**6.74**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

T_1: Funnel type trap — T_2: GME trap

T_3: BARI trap I — T_4: BARI trap II

L_1: Canopy level — L_2: Upper canopy level

Table 7. Combined effect of pheromone traps and trapping locations on brinjal fruit infestation in weight basis caused by BSFB

Treatments	Brinjal fruit per plant (weight basis)								
	Early fruiting stage			Mid fruiting stage			Late fruiting stage		
	Healthy (g)	Infested (g)	Infestation (%)	Healthy (g)	Infested (g)	Infestation (%)	Healthy (g)	Infested (g)	Infestation (%)
T_1L_1	605.45 ef	95.53 a	13.63 a	721.72 cd	135.63 a	15.83 b	592.37 cd	138.00 a	18.90 b
T_1L_2	583.50 f	93.60 a	13.84 a	699.73 d	139.60 a	16.63 a	564.93 d	142.30 a	20.12 a
T_2L_1	717.70 a	41.51 f	5.47 f	804.92 a	52.93 f	6.17 g	683.00 a	50.87 e	6.93 f
T_2L_2	697.73 ab	43.65 f	5.89 f	789.62 a	61.57 e	7.23 f	644.90 b	54.23 e	7.76 f
T_3L_1	642.80 cd	74.00 c	10.36 c	723.15 cd	97.85 b	11.92 c	623.03 bc	97.73 c	13.57 d
T_3L_2	628.12 de	81.53 b	11.48 b	708.90 cd	98.60 b	12.21 c	601.43 c	111.50 b	15.64 c
T_4L_1	682.73 ab	61.90 e	8.32 e	756.12 b	80.82 d	9.66 e	642.80 b	91.30 d	12.47 e
T_4L_2	668.78 bc	68.72 d	9.32 d	737.43 bc	90.28 c	10.91 d	617.90 bc	97.60 c	13.64 d
$LSD_{(0.05)}$	**34.15**	**4.28**	**0.85**	**30.63**	**5.82**	**0.56**	**31.56**	**4.75**	**1.00**
Level of significance	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**
CV (%)	**5.20**	**4.18**	**4.29**	**5.47**	**6.07**	**5.46**	**4.07**	**5.52**	**6.74**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

T_1: Funnel type trap T_2: GME trap
T_3: BARI trap I T_4: BARI trap II

L_1: Canopy level L_2: Upper canopy level

4.4.2 Mid fruiting stage

At mid fruiting stage, weight of healthy and infested fruits per plant and fruit infestation varied significantly due to different types of pheromone trap (Table 6). The highest weight of healthy fruits per plant was found in T_2 (797.27 g) followed by T_4 (746.78 g), while the lowest in T_1 (710.72 g). The lowest weight of infested fruits per plant was recorded in T_2 (57.25 g) followed by T_4 (85.55 g) and T_3 (98.22 g) but the highest in T_1 (137.62 g). The lowest fruit infestation was observed in T_2 (6.70%) followed by T_4 (10.28%) and T_3 (12.07%), while the highest fruit infestation was recorded in T_1 (16.23%).

Location of pheromone traps varied significantly in terms of weight of healthy and infested fruits per plant and fruit infestation at mid fruiting stage (Table 6). The highest weight of healthy fruits per plant was found in L_1 (732.45 g) and the lowest in L_2 (713.08 g). The lowest weight of infested fruits per plant was found in L_1 (108.19 g) while the highest in L_2 (112.55 g). The lowest fruit infestation was found in L_1 (12.90%) but the highest fruit infestation was recorded in L_2 (13.70%).

Combined effect of different types of pheromone traps and location of pheromone traps showed statistically significant variation in terms of weight of healthy and infested fruits per plant and fruit infestation at mid fruiting stage (Table 7). The highest weight of healthy fruits per plant was found in T_2L_1 (804.92 g) but the lowest in T_1L_2 (699.73 g). The lowest weight of infested fruits per plant was found in T_2L_1 (52.93 g) while the highest in T_1L_2 (139.60 g). The lowest fruit infestation was found in T_2L_1 (6.17%) and the highest in T_1L_2 (16.63%).

4.4.3 Late fruiting stage

At the late fruiting stage, weight of healthy and infested fruits per plant and fruit infestation varied significantly due to different types of pheromone trap (Table 6). The highest weight of healthy fruits per plant was found in T_2 (663.95 g) followed by T_4 (630.35 g and 612.23 g) and they were statistically similar, while the lowest in T_1 (578.65 g). The lowest weight of infested fruits per plant was found in T_2 (52.55 g) followed by T_4 (94.45 g) and T_3 (104.62 g), while the highest in T_1 (140.15 g). The lowest fruit infestation was found in T_2 (7.25%) followed by T_4 (13.06%) and T_3 (14.60%), while the highest fruit infestation was recorded in T_1 (19.51%).

Location of pheromone traps varied significantly in terms of weight of healthy and infested fruits per plant and fruit infestation at late fruiting stage (Table 6). The highest weight of healthy fruits per plant was found in L_1 (612.26 g) but the lowest in L_2 (586.07 g). The lowest weight of infested fruits per plant was found in L_1 (106.48 g) and the highest weight was recorded in L_2 (112.74 g). The lowest fruit infestation was recorded in L_1 (14.96%) while the highest in L_2 (16.23%).

Combined effect of different types of pheromone traps and location of pheromone traps showed statistically significant variation in terms of weight of healthy and infested fruits per plant and fruit infestation at late fruiting stage (Table 7). The highest weight of healthy fruits per plant was found in T_2L_1 (683.00 g) while the lowest in T_1L_2 (564.93 g). The lowest weight of infested fruits per plant was observed in T_2L_1 (50.87 g) but the highest weight was recorded T_1L_2 (142.30 g).

The lowest fruit infestation was found in T_2L_1 (6.93%) whereas the highest in T_1L_2 (20.12%).

The results regarding fruit infestation of brinjal by shoot and fruit borer indicated that highest number of healthy fruit, lowest number of infested fruit and lowest percentage of fruit infestation was found in T_2L_1 (GME pheromone trap located at canopy level). In contrast the lowest number of healthy fruit, highest number of infested fruit and highest percentage of fruit infestation was observed in T_1L_2 (Funnel type pheromone trap located at upper canopy level). This result agrees with report of Cork *et al*. (2003) who observed that the traps placed at crop canopy level caught significantly more male moths than placed 0.5 m above the canopy. Alam *et al*. (2003) also experienced the similar results. Thus GME type pheromone traps located at canopy level caught more adult male moths and reduced fruit infestation at different stages of crop growth.

4.5 Effect of pheromone traps on plant height, single fruit weight and yield of brinjal

Different pheromone traps placed at canopy level and upper canopy level of brinjal plant showed significant effect on plant height, single fruit weight and yield of brinjal.

4.5.1 Effect of pheromone taps on plant height

Plant height at last harvest of brinjal showed statistically significant variation due to effect of different pheromone traps (Table 8). The tallest plant (131.67 cm) was recorded in T_2 followed by T_4 (128.44 cm) having no significant difference between them but significantly different from other traps. The shortest brinjal plant was observed in T_1 (118.80 cm) followed by T_2 (123.44 cm) but significantly different from other treatments. Plant height also significantly differed at two locations of pheromone traps. The tallest plant was found in L_1 (122.58 cm) as against the shortest plant (118.96 cm) in L_2 (Table 8). Combined effect of different types of pheromone trap and location of pheromone traps showed statistically significant variation in terms of plant height at harvest (Table 9). The tallest plant was found in T_2L_1 (134.40 cm) which had lower level of shoot infestation by borer while shortest plant was recorded in T_1L_2 (116.51 cm) having higher percentage of shoot infestation. This result indicated that pheromone traps at canopy level caught the higher number of male brinjal shoot and fruit borer and reduced the shoot infestation by this obnoxious pest.

4.5.2 Effect of pheromone traps on weight of individual fruit

Weight of individual fruit of brinjal showed statistically significant variation due to different types of pheromone traps (Table 8). The highest weight of individual fruit was recorded in T_2 (77.51 g) which significantly different from other treatments. Whereas the lowest weight of individual fruit was found in T_1 (64.35 g) and T_3 (67.79 g) which are statistically similar with each other.

Weight of individual fruit of brinjal also significantly varied at two locations of different pheromone traps (Table 8). The highest weight of individual fruit was found in L_1 (69.39 g) while the lowest in L_2 (66.63 g).

Combined effect of different types of pheromone traps and their locations had significant effect on weight of individual fruit of brinjal (Table 9). The highest weight of individual fruit (78.90 g) was found in T_2L_1 (GME trap placed at canopy level) followed by 76.13 g in T_2L_2 (GME trap placed at upper canopy level) having significant difference between them. While the lowest weight of individual fruit (63.30 g) was recorded in T_1L_2 (Funnel type pheromone trap located at upper canopy level) having no significant difference with T_1L_1.

4.5.3 Effect of pheromone traps on fruit yield of brinjal

Yield per hectare of brinjal showed statistically significant variation due to different types of pheromone traps (Table 8). The highest yield was recorded in T_2 (45.36 t/ha) which was statistically different to 44.23 t/ha in T_4 and followed by T_3 (42.60 t/ha), whereas the lowest yield was found in T_1 (41.72 t/ha).

Table 8. Effect of pheromone traps and trapping locations on plant height and weight of individual fruit and yield

Treatments	Plant height (cm)	Weight of individual fruit (g)	Fruit yield (t/ha)
Pheromone Trap Types			
T_1	118.80 c	64.35c	41.72 b
T_2	131.67 a	77.51 a	45.36 a
T_3	123.44 bc	67.79 c	42.60 b
T_4	128.44 ab	73.20 b	44.23 ab
$LSD_{(0.05)}$	**5.40**	**3.51**	**2.51**
Level of significance	**0.01**	**0.01**	**0.01**
Trapping locations			
L_1	122.58 a	69.39 a	42.92 a
L_2	118.96 b	66.63 b	41.39 b
$LSD_{(0.05)}$	**3.42**	**2.22**	**1.51**
Level of significance	**0.05**	**0.05**	**0.05**
CV(%)	**4.69**	**4.26**	**4.92**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

T_1: Funnel type trap　　T_2: GME trap

T_3: BARI trap I　　T_4: BARI trap II

L_1: Canopy level　　L_2: Upper canopy level

The data in Table 8 also indicated that fruit yield of brinjal significantly varied in two locations due to pheromone traps. The highest yield (42.92 t/ha) was recorded in L_1 (canopy level) and the lowest yield (41.39 t/ha) in L_2 (upper canopy level.

In case of combined effect of different types of pheromone traps and their locations statistically significant variation was observed for weight of individual fruit (Table 9). The highest yield per hectare of brinjal was found in T_2L_1 (46.40 t/ha), while lowest fruit yield (40.75 t/ha) experienced in T_1L_2 (Funnel type trap located at upper canopy level). The result indicated that GME trap located at canopy level produced higher fruit yield of brinjal compared to other combinations of different traps and locations.

The results of the study indicated that GME type pheromone trap was more effective for catching the adult male moth of BSFB. Moreover trap located at canopy level was better for caught adult male moth. In case of combined effect GME type pheromone trap located at canopy level was more effective for caught adult moth and reducing shoot and fruit infestation. This result agreed with report of Cork *et al*. (2003) who observed that the pheromone traps placed at crop canopy level caught significantly more male moths than placed 0.5m above the canopy. Alam *et al*. (2003) also found the similar results. Thus GME type pheromone traps located at canopy level caught more adult male moths of brinjal shoot and fruit borer which reduced fruit infestation and produced more insect free fruit yield of brinjal at different stages of crop growth.

Table 9. Combined effect of pheromone traps and trapping locations on plant height and weight of individual fruit and yield

Treatments	Plant height (cm)	Weight of individual fruit (g)	Fruit yield (t/ha)
T_1L_1	121.10 cd	65.40 d	42.68 abc
T_1L_2	116.51 d	63.30 d	40.75 c
T_2L_1	134.40 a	78.90 a	46.40 a
T_2L_2	128.93 abc	76.13 ab	44.32 abc
T_3L_1	125.25 bc	68.65 cd	43.51 abc
T_3L_2	121.62 bcd	66.93 cd	41.69 bc
T_4L_1	129.89 ab	74.72 ab	45.20 ab
T_4L_2	127.00 abc	71.68 bc	43.25 abc
$LSD_{(0.05)}$	**7.64**	**4.97**	**3.56**
Level of significance	**0.05**	**0.05**	**0.05**
CV(%)	**4.69**	**4.26**	**4.92**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

T_1: Funnel type trap T_2: GME trap
T_3: BARI trap I T_4: BARI trap II

L_1: Canopy level L_2: Upper canopy level

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted during the period from November 2013 to April 2014 at the research farm of Sher-e-Bangla Agricultural University (SAU), Dhaka to study the effect of pheromone traps and trapping locations on capturing male moth of brinjal shoot and fruit borer and fruit yield of brinjal. Brinjal variety Shingnath was used as the test crop of this experiment. The experiment consisted of two factors: Factor A: Pheromone trap types (four type) as - T_1: Funnel type trap; T_2: GME trap; T_3: BARI trap I; T_4: BARI trap II; and Factor B: Location of pheromone traps (two locations) as - L_1: Canopy level; L_2: Upper canopy level. The two factorial experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Data were recorded on number of catch moth, infestation of shoot and fruit (number and weight basis), plant height, individual fruit weight and fruit yield and found statistically significant differences due to different types of pheromone trap, location of pheromone traps and their combined effect.

In case of different types of pheromone trap, the highest number of caught male BSFB (6.43) was recorded in T_2, whereas the lowest (4.66) in T_1.

Considering shoot infestation by BSFB the lowest shoot infestation was found in T_2 (5.21%), while the highest in T_1 (5.21%) at early fruiting stage. The lowest shoot infestation was found in T_2 (5.82%), while the highest in T_1 (13.78%) at mid fruiting stage. Similarly the lowest shoot infestation was recorded in T_2 (6.73%) at late fruiting stage, while the highest in T_1 (14.89%).

In case of fruit infestation on number basis, the lowest fruit infestation was found in T_2 (4.52%), while the highest in T_1 (12.65%) at early fruiting stage. At mid fruiting stage, the lowest fruit infestation was found in T_2 (5.92%) but the highest in T_1 (15.07%). At late fruiting stage, the lowest fruit infestation was found in T_2 (6.69%), while the highest in T_1 (18.21%). At early fruiting stage in weight basis, the lowest fruit infestation was found in T_2 (5.68%) but the highest in T_1 (13.73%). At mid fruiting stage, the lowest fruit infestation was found in T_2 (6.70%), while the highest in T_1 (16.23%). At late fruiting stage, the lowest fruit infestation was found in T_2 (7.25%), while the highest in T_1 (19.51%).

The tallest plant was recorded in T_2 (131.67 cm), whereas the shortest plant was found in T_1 (118.80 cm). The highest weight of individual fruit was recorded in T_2 (77.51 g), while the lowest in T_1 (57.18 g). The highest yield was recorded in T_2 (45.36 t/ha) and the lowest yield was found in T_1 (41.72 t/ha).

For location of pheromone traps the highest number of caught male BSFB (5.24) was found in L_1 and the lowest number (3.69) was recorded in L_2. At early fruiting stage the lowest shoot infestation was found in L_1 (8.07%) and the highest in L_2 (10.37%). At mid fruiting stage, the lowest shoot infestation was found in L_1 (10.78%) while the highest in L_2 (12.23%). At late fruiting stage, the lowest shoot infestation was experienced in L_1 (11.94%) but the highest in L_2 (13.98%). At early fruiting stage, the lowest fruit infestation was found in L_1 (9.44%) whereas the highest in L_2 (11.40%). At mid fruiting stage, the lowest fruit infestation was found in L_1 (11.81%) and the highest in L_2 (13.23%). At late fruiting stage, the lowest fruit infestation was found in L_1 (14.13%) while the highest in L_2 (15.68%). At early fruiting stage in weight basis, the lowest fruit infestation was found in L_1 (11.16%) while the highest in L_2 (11.81%). At mid fruiting stage, the lowest fruit infestation was recorded in L_1 (12.90%) but the highest in L_2 (13.70%). At late fruiting stage, the lowest fruit infestation was found in L_1 (14.96%) while the highest in L_2 (16.23%).

The tallest plant was found in L_1 (122.58 cm) and the shortest plant was recorded in L_2 (118.96 cm). The highest weight of individual fruit was observed in L_1 (69.39 g) but the lowest in L_2 (66.63 g). The highest yield was found in L_1 (42.92 t/ha) and the lowest in L_2 (41.39 t/ha).

In case of combined effect of different types of pheromone trap and location of pheromone traps, the highest number of male BSFB (7.34) was found in T_2L_1, while the lowest number (3.8) in T_1L_2. At early fruiting stage, the lowest shoot infestation was found in T_2L_1 (4.40%) while the highest in T_1L_2 (10.53%). At mid fruiting stage, the lowest shoot infestation was found in T_2L_1 (5.13%) but the highest in T_1L_2 (14.54%). At late fruiting stage, the lowest shoot infestation was found in T_2L_1 (5.97%) while the highest in T_1L_2 (16.24%).

The lowest fruit infestation (3.80%) was found in T_2L_1 at early fruiting stage while the highest in T_1L_2 (13.64%). At mid fruiting stage, the lowest fruit infestation (5.04%) was found in T_2L_1 but the highest in T_1L_2 (15.62%). At late fruiting stage, the lowest fruit infestation was found in T_2L_1 (5.41%) while the highest (18.89%) was recorded in T_1L_2. At early fruiting stage, the lowest fruit infestation was found in T_2L_1 (5.47%) and the highest was recorded T_1L_2 (13.84%). At mid fruiting stage, the lowest fruit infestation was found in T_2L_1 (6.17%) but the highest in T_1L_2 (16.63%). At late fruiting stage, the lowest fruit infestation was found in T_2L_1 (6.93%) and the highest in T_1L_2 (20.12%).

The tallest (134.40 cm) plant was found in T_2L_1, while shortest plant in T_1L_2 (116.51 cm). The highest weight of individual fruit was found in T_2L_1 (78.90 g), while lowest weight in T_1L_2 (63.30 g). The highest (46.40 t/ha) yield per hectare of brinjal was found in T_2L_1, while lowest in T_1L_2 (40.75 t/ha).

The results of the present study indicated that GME type pheromone trap was more effective, located at canopy level of brinjal was better for caught adult male moth of brinjal shoot and fruit borer, reducing shoot and fruit infestation and producing more insect free fruits of brinjal.

Based on the result of the experiment the following recommendations may be suggested:

1. GME type sex pheromone trap with at canopy level may be used for the management of brinjal shoot and fruit borer.
2. Such study needs to be conducted in different agro-ecological zones (AEZ) of Bangladesh for drawing any conclusion.

CHAPTER VI

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APPENDICES

Appendix I. Monthly record of air temperature, relative humidity, rainfall and sunshine hour of the experimental site during the period from November 2013 to April 2014

Month	*Air temperature (ºc)		*Relative humidity (%)	Total Rainfall (mm)	*Sunshine (hr)
	Maximum	Minimum			
November, 2013	25.8	16.0	78	00	6.8
December, 2013	22.4	13.5	74	00	6.3
January, 2014	24.5	12.4	68	00	5.7
February, 2014	27.1	16.7	67	30	6.7
March, 2014	31.4	19.6	54	11	8.2
April, 2014	33.4	23.2	67	78	8.3

* Monthly average,

* Source: Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka – 1212

Appendix II. Characteristics of soil of experimental field

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Agronomy field , SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B. Physical and chemical properties of the initial soil

Characteristics	Value
Sand (%)	27
Silt (%)	43
Clay (%)	30
Textural class	Silty-clay
pH	6.1
Organic matter (%)	1.13
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	23

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