CROSS-CUTTING ISSUES OF PESTICIDES AND HAZARD FREE MANAGEMENT OF BRINJAL SHOOT AND FRUIT BORER IN BANGLADESH

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*This is to certify that dissertation entitled **"CROSS-CUTTING ISSUES OF PESTICIDES AND HAZARD FREE MANAGEMENT OF BRINJAL SHOOT AND FRUIT BORER IN BANGLADESH"** submitted to the **Faculty of Agriculture,** Sher-e-Bangla Agricultural University (SAU), Dhaka in partial fulfillment of the requirements for the degree of **DOCTOR OF PHILOSOPHY IN ENTOMOLOGY**, embodies the result of a piece of bona fide research work carried out by **SUMON SAHA Registration no.*** **07-02316** *under my supervision and guidance. No part of the dissertation 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.

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DEDICATED
TO
MY BELOVED
PARENTS

ACRONYMS

Abbreviation	:	Full meaning
°C	:	Degree centigrade
AEZ	:	Agro-Ecological Zone
ANOVA	:	Analysis of Variance
BARI	:	Bangladesh Agricultural Research Institute
BARC	:	Bangladesh Agricultural Research Council
BSFB	:	Brinjal shoot and fruit borer
cm	:	Centimeter
DAT	:	Days after transplanting
EC	:	Emulcifiable Concentrate
ESFB	:	Eggplant shoot and fruit borer
g/gm	:	Gram
ha	:	Hectare
ICRISAT	:	International Crops Research Institute for the Semi-arid Tropics
IPM	:	Integrated Pest Management
Kg	:	Kilogram
L	:	Liter
LSD	:	Least Significant Difference
m	:	Meter
ml	:	Milliliter
mm	:	Millimeter
MT	:	Metric Ton
RCBD	:	Randomized Complete Block Design
RH	:	Relative Humidity
SAU	:	Sher-e-Bangla Agricultural University
SG	:	Soluble granular
SP	:	Soluble Powder
Tk	:	Taka
WP	:	Wettable powder

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CROSS-CUTTING ISSUES OF PESTICIDES AND HAZARD FREE MANAGEMENT OF BRINJAL SHOOT AND FRUIT BORER IN BANGLADESH

SUMON SAHA

ABSTRACT

Several studies were conducted in the experimental field of Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka, Bangladesh, during February 2016 to March 2020 to evaluate the cross-cutting issues of pesticides and hazard free management of brinjal shoot and fruit borer in Bangladesh. In Bangladesh, farmers have been facing problem in cultivation of brinjal in the field due to brinjal shoot and fruit borer (*Leucinodes orbonalis* Guenee), the most destructive insect pests of brinjal. A field survey was conducted with 310 brinjal farmers in five major brinjal growing districts. From the survey it was found that farmers of the major brinjal growing districts of Bangladesh are concerned about the brinjal shoot and fruit borer, destructive phase of BSFB and the favorable season of BSFB. 57.4% farmers under the survey used cocktail of synthetic insecticides (2-3 insecticides) against the BSFB. In Jashore region, farmers used insecticides two days interval. Beside this, the farmers were known about the hazard free management practices like using pheromone trap, bio-pesticides, etc. From the varietal screening it was found that, BARI Bt Brinjal-1 was most resistant cultivar against BSFB infestation, whereas BARI Begun-10 was most susceptible variety. The BARI Trap II showed the best performance resulting the lowest shoot infestation, fruit infestation by number and fruit infestation by weight (10.0, 8.08 and 9.44 percent, respectively) when it was set at canopy level in the brinjal field. The BARI Trap II also showed the best performance in producing highest fruit yield when it was set at canopy level in the brinjal field. From the comparative study of ecological and chemical approaches, it was revealed that, spraying of Marshal 20 (Carbosulfan) @ 3.0 ml/L of water at alternate 7 days interval showed the lowest fruit infestation by number, fruit infestation by weight, shoot infestation, and the highest length of healthy fruit, girth of healthy fruit, length of infested fruit, girth of infested fruit, number of bores fruit^{-1}, the highest weight of edible portion of infested fruit, the lowest weight of non-edible portion of infested fruit and yield (13.91%, 13.96%, 10.79%, 8.72 cm, 21.75 cm, 5.85 cm, 14.02 cm, 2.67 bores, 3.00 g/fruit, 0.39 g/fruit and 8.84 kg/plot, respectively) in the brinjal field. In the study of IPM packages for brinjal shoot and fruit borer management, IPM package-7 comprised of Pheromone Trap located at the canopy level @ 1 lure at 30 days interval + Spraying of Neem oil (azadirachtin) @ 3.0 ml/L and Marshal 20 EC (carbosulfan) @ 3.0 ml/L of water at alternate 7 days interval, respectively showed the best performance and found the lowest fruit infestation by number, fruit infestation by weight, shoot infestation, and the highest length of healthy fruit, girth of healthy fruit, length of infested fruit, girth of infested fruit, number of bores fruit^{-1}, the highest weight of edible portion of infested fruit, the lowest weight of non-edible portion of infested fruit and yield (13.76%, 14.86%, 10.85%, 8.67 cm, 22.16 cm, 5.84 cm, 13.96 cm, 1.33 bores, 0.48 kg, 0.05 kg and 8.77 kg/plot, respectively) in the brinjal field.

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CHAPTER I

INTRODUCTION

Brinjal, *Solanum melongena* L. belonging to the family Solanaceae, is the most common, popular and principal vegetable in Bangladesh and other parts of the world. It is locally known as '*Begoon*' and its early European name is 'Eggplant'. It is grown extensively in Bangladesh, India, Pakistan, China and the Philippines. Brinjal is a lot of eatables among widely grownup vegetables in many components of the planet (Mahanta and Kalita 2020). Brinjal is the second most important vegetables crops in Bangladesh after potato in relation to its total production (Anon. 1996; Rashid 1993). The major brinjal growing districts of Bangladesh are Bogura, Chattogram, Cumilla, Dhaka, Dinajpur, Faridpur, Jamalpur, Jashore, Khagrachhari, Khulna, Mymensingh, Manikganj, Narsingdi, Rangamati, Rangpur, Rajshahi, Sirajganj, Thakurgaon and Tangail (BBS 2020). This useful crop is grown all the year round in Bangladesh. During 2020-21 year in Rabi season, it covers 83277.36 acres of land with a production of 384841.03 MT and in Kharif season, it covers 49274 acres area with a production of 202371 MT (BBS 2021) with about 25.4% of the total vegetable area of the country, with a production rate of 3.29 MT/acre. But the yield per unit area is quite low since the insect pests cause 30 – 40% losses in general and even 100% losses in case of menace if no control measure is applied (Rahman 2016). Ali *et al.* (2017) reported that brinjal is susceptible to attack of 19 insect pests in Bangladesh from seedling to fruiting stage including brinjal shoot and fruit borer (BSFB) (*Leucinodes orbonalis* Guenee), epilachna beetle (*Epilachna vigintioctopunctata* Fab., *E. dodecastigma*), brinjal leaf roller (*Eublemma olivacea* Walker), aphid (*Aphis gossypii* Glover), Jassid (*Amrasca biguttula biguttula*), etc. Hill (1983) reported that 50 insect pests cause damage to brinjal. Among these insect pests, brinjal shoot and fruit borer (BSFB), *L. orbonalis* is one of the most destructive insect pests of brinjal in Bangladesh (Latif *et al.* 2009; Alam *et al.* 1982). It is the most noxious and destructive pest of brinjal and widely distributed in South Asian countries (Talekar 2002). *L. orbonalis* adversely affects both quality and quantity of brinjal. The damage caused by brinjal shoot and fruit borer varies from 12-16% for shoot and 20-63% for fruit (Mannan *et al.* 2015; Alam *et al.* 1982). The yield loss up to 60-80% (Kaur *et al.* 2010; Krishnaiah and Vijay 1975) was recorded in brinjal cultivation by the infestation of *L. orbonalis*. Sometimes, the yield loss caused by this pest has been estimated more than 85% (Rashid *et al.* 2003) and 86% (Ali *et al.* 1996) in Bangladesh; 85.8% (Patnaik 2000), 75% (Singh *et al.* 2005) and 95% (Naresh *et al.* 1986) in India.

The situation of brinjal production is in threat in the recent years due to increased cost of production for the management of insect pest. Farmers of Bangladesh, in most cases, solely depend on insecticides for the management of this pest and facing problem of safe management practices against insect pests of these crops and do not get good and marketable yield. Farmers still rely solely on insecticides for BSFB control, which is seriously hazardous, uneconomic and unacceptable that are impairing ecology, natural enemies and creating health hazards, increased production costs, etc. (Alam *et al.* 2003; Pedigo 2002). Hasanuzzoha (2004) reported that within a cropping season farmers applied insecticides on an average 99 times for brinjal at Jashore region that ranged from 30 to 300 times in a cropping season of brinjal. Rahman (2006) also reported that in a growing season of 4 to 6 months in Jashore district, as many as 150 applications of insecticides with at least once a day during peak period were required to suppress the insect pests in brinjal. It was also found that many farmers sprayed insecticides every day or every alternate day, even twice a day in brinjal at Jashore region. Nonetheless, brinjal shoot and fruit borer is very much difficult to control with the currently available insecticides as because of its nature of damage and development resistance against insecticides (Alam *et al.* 2003). This is the prime crisis of farmers over the country. But information regarding the indiscriminate uses and the hazardous impacts of pesticides during the control of insect pests in vegetables including brinjal is limited in Bangladesh. The farmers are also far behind the use of safe and environment friendly management practices of insect pests in brinjal field. Frequent use of systemic insecticides renders the vegetables poisonous, ecologically unsafe and economically unviable. It is now urgently required to find out an alternative and non-insecticidal method for controlling brinjal shoot and fruit borer (Mannan *et al.* 2015).

Various IPM tools viz. cultural practices including crop hygiene, use of resistant varieties, biological control agent, biopesticides, etc. are alternative ways to manage the pest efficiently, to promote the activities of natural enemies, to reduce the threat from potential insect pests. Morphological and physiological characters such as trichome density, toughness of shoot and thickness of epidermal layer of fruit, narrow pith, compactness of vascular system, etc. of host plants inhibits the growth and development of brinjal shoot and fruit borer during infestation (Ali *et al.* 1994; Mallik *et al.* 1986; Chelliah and Sreenivashan 1983). In Bangladesh, very few research findings have been so far reported on the host plant resistance of BSFB (Islam 2014). Now-a-days, importance is given on the use of resistant genotype against BSFB like *Bt* brinjal. Because the use of resistant variety is non-toxic and safe alternatives to the conventional chemical control (Dolui and Debnath 2010; Anil and Pandey 2001). There was no naturally selected brinjal varieties available having resistance to BSFB except transgenic *Bt* brinjal varieties.

Latif (2007) reported that nimbicidine and flubendiamide were comparatively safer for natural enemies and insect pest management of brinjal. Tohnishi *et al.* (2005) reported that flubendiamide was highly toxic to Lepidopteran insect pests but it was very safe for different natural enemies like ladybird beetles, spiders, parasitic wasp, lacewings, predatory bug and predatory mite (Awal *et al.* 2017). Thus, the present trend of pest management moves towards the development of eco-friendly management practices through Integrated Pest Management (IPM). The integration of pheromone trap as an effective component of IPM program (Mazumder and Khalequzzaman 2010; Chatterjee 2009; Cork *et al.* 2001; Gunawardena and Attygalle 1989) in monitoring pest population for early decision making as well as mass trapping of pests including BSFB using lures baited with a killing agent. Based on the moth capturing in pheromone trap, it is easy to recognize the prevailing life stages of brinjal shoot and fruit borer at the brinjal cultivation on a particular time and which will direct to select the proper management practices against brinjal shoot and fruit borer (Niranjana *et al.* 2017).

Integrated management practice is banking on removal of brinjal shoot and fruit borer infested shoots and fruits, mass trapping of adult moth with sex pheromone, cultivation of resistant/tolerant brinjal variety and judicious use of insecticides to allow proliferation of natural enemy population and it is useful as a low-cost sustainable management practice for managing BSFB, production of safe fruit as well as minimizing the yield loss of brinjal. Integrated Pest Management (IPM) resulted effective control of shoot and fruit borers, as well as the highest benefit-cost ratio (Duara *et al.* 2003). To address this serious issue, AVRDC, "The World Vegetable Center" developed, validated, and promoted an IPM strategy for the control of EFSB in South Asia from 2000-2005 (Alam *et al.* 2003, 2006). This IPM strategy includes using sex pheromones to trap and kill male adults (Cork *et. al.* 2001, 2003). The combination of different control measures was more successful than that of sole one, which influenced the farmers for the application of suitable control measures among different management practices considering hazard-free brinjal production (Alam *et al.* 2003).

The implementation of the research will gear up the know-how of the missuse of insecticides for controlling brinjal shoot and fruit borer used by the farmers as well as in selecting eco-friendly management practices especially utilization of insect sex pheromones and botanical based products against brinjal shoot and fruit borer for successful and hygienic brinjal production.

OBJECTIVES

- To identify the cross-cutting issues of insecticides commonly used by the farmers during the management of brinjal shoot and fruit borer (BSFB);
- To find out the resistant/tolerant brinjal varieties against brinjal shoot and fruit borer;
- To find out the best-suited type of pheromone trap and its setting position in the field to capture BSFB adult;
- To find out the efficacy of botanicals and other non-chemical management practices in comparison with chemical insecticides against BSFB; and
- To develop integrated management package(s) against brinjal shoot and fruit borer considering safe and hazard free brinjal production.

CHAPTER II

REVIEW OF LITERATURE

Brinjal shoot and fruit borer mostly considered devastating pest of brinjal because of its wide range of attacking capacity of brinjal, tomato, potato, etc. The literatures of the biology of brinjal shoot and fruit borer is very sporadic. But the management practices against brinjal shoot and fruit borer is frequent. For the purpose of the study, the most relevant information is given under the following sub-headings:

2.1. Brinjal shoot and fruit borer

2.1.1. Scientific classification

The taxonomic position of brinjal shoot and fruit borer is given bellow:

Kingdom: Animalia

Phylum: Arthropoda

Class: Insecta

Order: Lepidoptera

Family: Crambidae

Genus: *Leucinodes*

Specis: *L. orbonalis*

2.1.2. Origin and distribution

In Bangladesh this pest enjoys a country wide distribution. Besides, Bangladesh it is also found in India, Sri Lanka, Mayanmar, Malaysia, Congo, South Africa, etc. The worldwide distribution of brinjal shoot and fruit borer is presented in Appendix-I.

2.1.3. Host range

L. orbonalis is practically monophagous, 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 host plants are: *Solanum melongena* Linnaeus (eggplant), *Solanum tuberosum* Linnaeus (potato) but there are several minor hosts, like *Ipomoea batatas* Linnaeus (sweet potato), *Lycopersicon esculentum* Mill (tomato), *Pisum sativum* var. *arvense* Linnaeus (Austrian winter pea) *Solanum indicum* Linnaeus, *Solanum myriacanthum* Dunal, *Solanum torvum* Swartz (turkey berry) and wild host *Solanum gilo* Raddi (gilo), *Solanum nigrum* Linnaeus (black nightshade) (CABI 2022). In addition, *Solanum anomalum* Thonn (Singh and Kalda 1997) and *Solanum macrocarpon* Linnaeus (Kumar and Sadashiva 1996) are wild hosts of *L. orbonalis*.

The brinjal shoot and fruit borer is the most obnoxious pest of eggplant and also infest potato, pods of green peas and can also be reared on *Solanum torvum* Swartz (Atwal 1986; Alam and Sana 1962). Hill (1983) also reported that Tomato, potato and peas are attacked by this pest. The pest also attacks other wild species of Solanum (Karim 1994). According to Ishaque and Chaudhuri (1983) the alternate hosts of BSFB were *Solanum nigrum, S. torvum, S. indicum, S. muricatum* and potato.

2.1.4. Damages caused by brinjal shoot and fruit borer

Damage by this pest starts soon after transplanting the crop and continues till the harvest of the fruits. FAO (2003) reported that brinjal shoot and fruit borer was the most serious pest of brinjal especially during the fruiting stage. The extent of fruit damage varied from 1.00 to 90.00% (Butani and Jotwani 1984) in India but Dhankar (1988) found 37.00 to 63.00% in different stages.

In Bangladesh, Rahman *et al.* (2006) reported 44.49% fruit infestation, while Islam and Karim (1991) found 67.00% fruit infestation. Alam *et al.* (2003) reported that the pest damage 31.00 and 33.00% of the brinjal crop in 1999 and 2000 croping year, respectively, while Alam (1969) reported 20.00-63.00% fruit and 12.00-16.00% shoots infestation. The percent fruit infestation was varied on different varieties of brinjal.

Kabir *et al.* (1996) found 34.97 (var. Pusa purple long) to 61.39% (var. Uttara) fruit infestation among 17 varieties. Fruit infestation was the highest (91.86%) on Islampuri and that was the lowest (32.81%) on (Rahman *et al.* 2006).

2.1.5. Seasonal abundance

The pest is reported from regions of eggplant cultivation in Africa, South of the Sahara and South-East Asia, including China and the Philippines (CABI 2007). In Asia, it is the most important and the first ranked pest of India, Pakistan, Sri Lanka, 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).

Brinjal shoot and fruit borer infestation is varied significantly in relation to plant age and season. The peak shoot infestation was 8.56% in the 10th week of transplanting. No infestation of BSFB was found up to 5 weeks of transplanting. The shoot infestation was initiated in the 6^{th} week of transplanting which increased to a little higher level in the next week. Then it showed an exponential increase of shoot infestation up to 10^{th} week after which it declined steadily. Flowering and fruit setting were started in the 9^{th} week of transplanting. Infestation of brinjal shoot and fruit borer (BSFB) was shifted to fruits from shoots causing a steady decline in the trend of shoot infestation. Plant age had significant effect (r^2 =0.87) on fruit infestation. The fruit infestation reached the highest level (38.56%) in 14^{th} week of transplanting. However, the level of infestation at different ages of the plant may vary depending on the location, temperature, variety, etc. The shoots and fruits of brinjal plant were found to be infested by BSFB throughout the year, although the level of infestation varied. Maximum shoot and fruit infestation was found in the month of September (Mannan *et al.* 2015).

Shoot and fruit borer in brinjal is the major pest causing severe losses to marketable yield throughout the country. A moderate range of temperature coupled with high humidity was found to be favorable for the borer. Brinjal crop planted during March to September recorded a higher level of shoot (3.4 - 10.62%) and fruit damage (53.39 - 61.23%) than the crops planted during remaining months (Senapathi, 2006). Singh *et al.* (2009) revealed that *L. orbonalis* infested the crop shoots during the end of August (73.33%), which peaked (86.66%) in the third week of September with an intensity of 2.09 per plant. The shoot damage ranged between 30.23 and 36.23%, while fruit damage ranged 37.51 to 42.23 % from May to July 2008-2009.

Murthy (2001) found that the pest was relatively more abundant during September month on potato shoot under protected condition. Infestation of *L. orbonalis* in brinjal shoots started in the first week of August and remained up to second week of October, with peak in second week of September. Infestation in shoots decreased after fruit setting and completely disappeared thereafter. The infestation in fruits was recorded in the second week of September and remained up to third week of October. The infestation increased gradually and reached maximum in the first week of October (63.09% on number basis and 51.45% on weight basis). The infestation of fruit borer started declining and persisted only up to third week of October. The effect of abiotic factors on *L. orbonalis* revealed that maximum temperature had positive significant effect on fruit infestation; whereas, negative significant correlation was computed between borer infestation and minimum temperature.

Naqvi *et al.* (2009) reported that relative humidity had positive significant effect on shoot and fruit borer. Rainfall had no effect on shoot and fruit borer infestation.

Bharadiya and Patel (2005) reported that the activity of shoot and fruit borer, *L. orbonalis,* on shoots started in the first week of September (4.9% incidence) and reached the peak level (17.1%) before migrating to fruits by fourth week of October.

Dhamdhere *et al.* (1995) found that pest commenced from 45 and 55 days after transplanting of brinjal seedlings in summer and Kharif season, respectively and continued up to harvest. The infestation in summer and Kharif season ranged from 7.56 to 23.55 and 17.24 to 30.87 on shoots and 10.06 to 25.27 and 23.34 to 47.75 per cent fruit number and weight basis, respectively.

Tripathi *et al.* (1996) revealed that the highest incidence of the pest on shoots was noticed in 46^{th} standard week (8.05 %) and the lowest in 31^{st} standard week (0.98 %). The highest fruit damage occurred at low mean temperature of 19.4°C and 61 percent relative humidity. The extent of damage on weight basis ranged between 4.03 and 57.01 per cent and followed a similar trend as on number basis.

Kumar *et al.* (1997) observed that infestation by the pest was significantly affected by temperature than other environmental factors. The peak shoot (15.71%) and fruit infestation (71.09% by weight) were recorded during the last week of June and first week of July, respectively.

Singh *et al.* (2009) observed that shoot infestation during 4th week of August, 2008 and the incidence had non-significant relationship with temperature, relative humidity and rainfall but significant relationship with coccinellids and spiders. In another study, Singh and Singh (2003) observed that incidence of shoot and fruit borer was started in the month of April and continued till the end of the June.

The peak period of the pest on shoot was recorded in the first week of June (29.45%) and fourth week of May (25.24%) during the first and second cropping seasons respectively. However, the incidence of the pest on fruit was the highest during the second week of June, 2003 (67.16%) and third week of June, 2004 (72.25%). The correlation study revealed that average temperature and relative humidity showed significant positive association while average sunshine observed significant negative association with the infestation of the pest on brinjal.

The seasonal history of brinjal shoot and fruit borer varies considerably due to different climatic conditions throughout the year. Hibernation does not take place and the insects are found active in summer months, especially in rainy season. Shoot and fruit borer is very injurious to brinjal during the rainy and summer seasons. The fruit infestation may even reach above 60% during the rainy seasons in Bangladesh and more than 90% in India (Kalloo 1988). It is revealed from a study that population of *L. orbonalis* began to increase from the first week of July and peaked (50 larvae per 2 sq.m) during the third week of August. The population of this pest was positively correlated with average temperature, mean relative humidity and total rainfall. Brinjal shoot and fruit borer are less active during February- April. During winter months, different stages of this pest last for longer periods and overlapping generations were observed.

Jat *et al.* (2002) conducted an experiment to study the seasonal incidence of shoot and fruit borer (*L. orbonalis* Guen.) on eggplant (*Solanum melongena* L.) in Rajasthan during 1999 and 2000. The seasonal incidence of *L. orbonalis* on aubergine cv. Pusa Purple Round was studied. The infestation of shoot and fruit borer started from fourth week of August and reached to its peak in the last week of October, peaked in the fourth week of October and continued up to second week of December. Significant positive correlation was observed between fruit borer infestation and maximum temperature, while minimum temperature had no effect. The relative humidity had no effect. The relative humidity had no effect on fruit infestation during 1999 but showed significant positive correlation in the year of 2000.

2.1.6. Life cycle

a) Fecundity

Sharma *et al.* (2017) conducted a study on biology of brinjal shoot and fruit borer (*Leucinodes orbonalis* Guenee) on brinjal cvs. 'Neelkanth' and 'Pusa Purple Long' was carried out during 2016 in the laboratory conditions. From the study it was found that the incubation period was 3.72 and 3.51 days on 'Neelkanth' and 'Pusa Purple Long' whereas the larval period was found 13.52 and 14.39 days on 'Pusa Purple Long' and 'Neelkanth'. The total developmental period was 24.52 and 26.41 days on 'Pusa Purple Long' and 'Neelkanth' cultivars, respectively. The fecundity was more on 'Pusa Purple Long' (210.20 eggs per female), as compared to 'Neelkanth' cultivar (193.40 eggs per female). From this study, it was also found that developmental biology was shorter in 'Pusa Purple Long' whereas longer in 'Neelkanth'.

b) Egg incubation

The egg took incubation period of 3-5 days in summer and 7-8 days in winter and hatch into dark white larvae (Rahman 1997). The findings were also in accordance with Bindu *et al.* (2013), Kumar *et al.* (2011), Wankhede *et al.* (2009), Jat *et al.* (2003) and Pal *et al.* (2003) have reported the egg period varied from 3 to 6 days at different laboratory conditions.

c) Larva

Newly hatched larva was glabrous, dirty white in colour, the body colour of the larva changed from whitish to dark pinkish. The larva passed through five instars to become full grown larva. In this study it was found that the larval period ranged from 9 to 12 days during three generations and average larval period recorded was 11.29 days. These findings are in accordance with Maravi *et al.* (2013), Kumar *et al.* (2011), Pal *et al.* (2003), Yin (1993), Sandanayake and Edirisinghe (1992) and Alam *et al.* (1982) have found that larval period ranged from 9 to 18 days at different laboratory conditions.

d) Pupa

The pupation took place on the glass jar, soil, Moslin cloth, sometimes inside the fruits and on the leaves of the plants. The pupal colour was pinkish which later turned dark brown. The pupa was obtect type with blunt anterior end and conical in shape posteriorly, having distinct body divisions and a pair of spiracles on each abdominal segment. In this study it was observed that the pupal period ranged from 7 to 8 days during three generations, with an average of 7.35 days. The pupal period lasted 6 to 17 days depending upon temperature (Alam *et al.* 2003). The findings were also found similar with Maravi *et al.* (2013), Onekutu *et al.* (2013), Radhakrishore *et al.* (2010), Wankhede *et al.* (2009), Jat *et al.* (2003), Pal *et al.* (2003), Singh and Singh (2001), Suresh *et al.* (1996), Yin (1993), Baang and Corey (1991) amd Alam *et al.* (1982) reported that pupal period lasted for 7 to 12 days at different laboratory conditions.

Allam *et al.* (1982) who reported that the pupal period varied from 7 to 11 days under laboratory conditions while Mainali (2014) reported that the pupal period varied from 7-10 days. Comparatively longer duration of pupal period was reported by Singh and Singh, (2003), Jat *et al.* (2002), Baang and Corey (1991) and Mehto *et al.* (1983) which could be attributed to variation in host on the larvae were reared.

e) Adult

The adult moths were small in size with whitish wings, blackish brown head and thorax. The whitish wings had brown and black markings which were bigger on the forewings. Hind wings were dirty white with black dots and angled margin. The abdomen of female was swollen and seemed to be ovate in structure whereas, in the males, it was thinner and cylindrical. The abdominal tip of females was tapering and pointed towards the end whereas, in males it was blunt with some white hairy structures. In this study, it was recorded that adult longevity varies from 3.5 to 4.5 days during three generations, with an average of 4.03 days. Various scientists have reported fluctuating results on biology of shoot and fruit borer *viz.* Maravi *et al.* (2013), Onekutu *et al.* (2013), Pramanik *et al.* (2012), Kumar *et al.* (2011), Wankhede *et al.* (2009), Harit and Shukla (2005), Jat *et al.* (2003), Singh and Singh (2001), Baang and Corey (1991), Mehto *et al.* (1983) and Alam *et al.* (1982) who found that adult longevity lasted from 2 to 7 days at different laboratory conditions.

The moths emerged out from pupae of *L. orbonalis* were collected, reared and distinguished based on sexual diamorphism characters. This study indiacted slight dominance of female population. In this study it was recorded that male and female ratio varied from 1:1.6 to 1:2.25 during three generations, with an average ratio of 1:1.95. These studies were in confirmity with the study of Pal *et al.* (2003), Maravi *et* *al.* (2013) and Onekutu *et al.* (2013) who have reported that male female ratio varied from 1:1.07 to 1:2 at different laboratory conditions.

Jat *et al.* (2003) who reported the longevity of male and female were as 1.82 days and 3.12 days, respectively but contrary to the findings of Kavitha *et al.* (2008) who observed that male longevity was 3.50 days while, the female longevity was 5.70 days. The findings were also in contrary with the findings of Harit and Shukla (2005), Singh and Singh (2003), Baang and Corey (1991) and Mehto *et al.* (1983) who reported that male and female lifespan varied few days 1.5-2.4 and 2.0-3.9 days, 4.0 and 7.5 days, 3.53 and 5.80 days, 3.53 and 5.51 days, respectively. These variations in the duration of life stages might be due to variable food and temperature.

f) Total life cycle

The total life cycle of shoot and fruit borer, *L. orbonalis* varied from 23.17 to 28 days during three generations, with an average of 26.40 days. These studies were in confirmity with the study of Maravi *et al.* (2013), Onekutu *et al.* (2013), Pramanik *et al.* (2012), Wankhede *et al.* (2009), Patial *et al.* (2007), Ghosh *et al.* (2005), Jat *et al.* (2003), Pal *et al.* (2003), Suresh *et al.* (1996) and Alam *et al.* (1982) who reported that total life cycle period varied from 19 to 44 days at different laboratory conditions.

Rahman *et al.* (2006) who reported that the total larval period varied from 12-15 days. These results also showed similarity to the findings of Radhakrishore *et al.* (2010) who reported that the total larval period varied from 15-18 days. Jat *et al.* (2002) Baang and Corey (1991) and Mehto *et al.* (1983) who reported the total larval periods of 17.5, 15.0 and 18.6 days, respectively. On the other hand, Singh and Singh (2003) reported a larval period of 12.83 days.

Onekutu *et al.* (2013) who reported the total developmental period varied from 26.61 days to 28.57 days with an average of 27.49 days while Mannan *et al.* (2015) reported that the total developmental period of this pest varied from 17 to 28 days. A range of 22 to 27 days as the total developmental period of brinjal shoot and fruit borer was reported by Philrice (2007) and a mean of 28.82 days was reported by Gupta and Kauntey (2007). Jat *et al.* (2002) and Kumar and Johnsen (2000) who reported a total developmental period of 25.8 days and 27.07 days, respectively. Harit and Shukla (2005) and Singh and Singh (2003) on the other hand reported a longer developmental period of 36.82 days and 42.5 days, respectively which may be due to difference, in prevailing climatic conditions under which the pest was reared. Besides, variations in host might have contributed to the difference in the developmental period.

Kumar *et al.* (2011) who reported the pre-oviposition period of 1.15 days and is also in agreement with the findings of Mannan *et al.* (2015) who reported the pre-oviposition averaged 1.35 days. The period of egg laying i.e. after the pre-oviposition period till the termination of egg laying was considered as the oviposition period.

2.2 Nature of damage

Shoot and fruit borer in brinjal is the major pest causing severe losses to marketable yield throughout the country. A moderate range of temperature coupled with high humidity was found to be favourable for the borer. Brinjal crop planted during March to September recorded a higher level of shoot (3.4 - 10.62%) and fruit damage (53.39 - 61.23%) than the crops planted during remaining months (Tripathi and Senapathi 1998).

Singh *et al.* (2000) revealed that *L. orbonalis* infested the crop shoots during the end of August (73.33%), which peaked (86.66%) in the third week of September with an intensity of 2.09 per plant. The shoot damage ranged between 30.23 and 36.23%, while fruit damage ranged 37.51 to 42.23 % from May to July. Maximum and minimum temperature, evaporation and sun shine hours had positive association with shoot damage, while relative humidity had negative influence.

Murthy (2001) found that the pest was relatively more during September month on potato shoot under protected condition. Infestation of *L. orbonalis* in brinjal shoots started in the first week of August and remained up to second week of October, with peak in second week of September in both the years. Infestation in shoots decreased after fruit setting and completely disappeared thereafter. The infestation in fruits was recorded in the second week of September and remained up to third week of October. The infestation increased gradually and reached maximum in the first week of October (63.09% on number basis and 51.45% on weight basis). The infestation of fruit borer started declining and persisted only up to third week of October. The effect of abiotic factors on *L. orbonalis* revealed that maximum temperature had positive significant effect on fruit infestation; whereas, negative significant correlation was computed between borer infestation and minimum temperature. Relative humidity had positive significant effect on shoot and fruit borer. Rainfall had no effect on shoot and fruit borer infestation (Naqvi *et al.* 2009).

Bharadiya and Patel (2005) reported that the activity of shoot and fruit borer, *L. orbonalis*, on shoots started in the first week of September (4.9% incidence) and reached the peak level (17.1%) before migrating to fruits by fourth week of October.

Dhamdhere *et al.* (1995) found that pest commenced from 45 and 55 days after transplanting of brinjal seedlings in summer and Kharif season, respectively and continued up to harvest. The infestation in summer and Kharif season ranged from 7.56 to 23.55 and 17.24 to 30.87 on shoots and 10.06 to 25.27 and 23.34 to 47.75 per cent fruits number and weight basis, respectively.

Tripathi *et al.* (1996) revealed that highest incidence of the pest on shoots was noticed in 46th standard week (8.05 %) and lowest in 31st standard week (0.98 %). The highest fruit damage occurred at low mean temperature of 19.4°C and 61 percent relative humidity. The extent of damage on weight basis ranged between 4.03 and 57.01 per cent and followed a similar trend as on number basis.

Kumar *et al.* (1997) observed that infestation by the pest was significantly affected by temperature than other environmental factors. The peak shoot (15.71%) and fruit infestation (71.09% by weight) were recorded during the last week of June and first week of July, respectively.

Singh *et al.* (2009) observed that shoot infestation during 4th week of August, 2008 and the incidence had non-significant relationship with temperature, relative humidity and rainfall but significant relationship with coccinellids and spiders.

Singh *et al.* (2011) observed that incidence of shoot and fruit borer was started in the month of April and continued till the end of the June. The peak period of the pest on shoot was recorded in the first week of June (29.45%) and fourth week of May (25.24%) during the first and second cropping seasons, respectively. However, the incidence of the pest on fruit was highest during the second week of June, 2003 (67.16%) and third week of June 2004 (72.25%). The correlation study revealed that average temperature and relative humidity showed significant positive association while average sunshine observed significant negative association with the infestation of the pest on brinjal.

Brinjal shoot and fruit borer is considered to be the most destructive pest of brinjal in all part of India (Wargantiwar *et al.* 2010; Mote 1976).

2.3. Management

There are several ways to manage insect pest of the crops. So, for management of brinjal shoot and fruit borer farmers practiced cultural, mechanical, resistant varietiea, biological, botanical, checmical, IPM, etc. management systems. The management practices are:

2.3.1. Cultural management

Fertilizer management

The effect of nitrogen, phosphorus and potassium fertilizers on the incidence of noctuid *E. vittella* on okra was studied by Kumar and Urs (1988) in the field in Karnataka, India. The highest infestations were recorded in the plots treated with 250 and 30 kg of nitrogen and potassium per hectare, respectively. There were positive correlations between nitrogen uptake by the plant and *E. vittella* infestation. But there was negative correlation between potassium uptake by the plants and its infestation.

Mallik and Lal (1989) reported that application of neem oil cake and fertilizer (2.5 kg of each on 200 square meter plot) or of neem oil cake alone (5 kg/plot) reduced *Earias* spp. of okra infestation and increased yield.

Intercropping

Amin (2004) found that infestation of brinjal shoot by brinjal shoot and fruit borer was higher in case of monoculture of sole brinjal than brinjal + onion, brinjal + garlic, brinjal + chili, brinjal + coriander intercrop combination. The lowest infestation was found in brinjal + coriander combination. In case of fruit infestation in brinjal by brinjal shoot and fruit borer, Amin (2004) also found that lower fruit infestation in intercropping of brinjal + coriander, brinjal + chili, brinjal +onion, brinjal + garlic in comparison to that of brinjal alone.

Andow (1991) and Risch *et al.* (1983) found that intercropping had lower pest infestation than monocultures. In the tropical low lands of Mexico, Letourneau (1986) was found the similar result in maize + cowpea + squash intercropping. In a maize +

bean intercropping system, Van Huis (1981) and Francis *et al.* (1978) claimed lower attack rates of *Spodoptera frugiperda* in this system compared to a maize monoculture. Dempster and Coaker (1974) found that the colonization of cabbages by *Erioschia brassicae* and *Pieris rapae* was greatly interfered with when the cabbages were sown with white and red clover.

Haque *et al.* (2001) and Shah *et al.* (1991) where they found a higher gross return from intercropping than their corresponding sole crops. The highest gross return (BDT 316320 ha^{-1}) was recorded from the brinjal + fenugreek intercropping system followed by brinjal + radhuni (BDT 254240 ha^{-1}). Fenugreek based intercropping system provided better return than other intercropping systems. Higher yield of fenugreek than other intercrops contributed the increment of gross return in the intercropping system. In sole cropping, the highest gross return (BDT 183780 ha^{-1}) was recorded from brinjal followed by fenugreek and the lowest (BDT 30400 ha^{-1}) from coriander.

Razzak *et al.* (2015) conducted a study to evaluate the effectiveness of polyculture crop system in suppressing major insect pests of brinjal. Four Polyculture combinations, viz., brinjal + coriander, brinjal + fenugreek, brinjal + chili, brinjal + radhuni were tested. Five mono crops of brinjal, coriander, fenugreek, chili and radhuni were also grown to compare the effectiveness of polyculture crop system. The results revealed that polyculture had a lower pest population with more abundance of natural enemies as compared to mono crop. The maximum per cent reduction of fruit infestation of brinjal by brinjal shoot and fruit borer in weight over sole brinjal was found in brinjal + coriander (40.23%) followed by brinjal + radhuni (37.06%) combination. All the polyculture crop combinations showed higher biological efficiency than mono crop where brinjal + fenugreek provided the highest economic return (BDT-316320 ha^{-1}). It was demonstrated that a change in the cropping pattern or vegetation diversity could change the pest abundance effectively and eco-friendly suppressed the major insect pests of brinjal.

2.3.2. Biological control

Bacillus thurengiensis resulted maximum shoot and fruit infestation, less effective and more expensive controlling the pest. The results were supported by Mathur and Jain (2009).

Trichogramma are extremely tiny wasps in the family *Trichogramma*tidae. While it is uncommon for an insect's scientific name, especially one so long and unusual as *Trichogramma*, to also become its common name, the commercial development of this natural enemy and the fact that it attacks so many important caterpillar pests has earned it a place in the popular vocabulary of many pest management advisors and producers (Hossain 2010).

Trichogramma wasps occur naturally in almost every terrestrial habitat and some aquatic habitats as well. They parasitize insect eggs, especially eggs of moths and butterflies. Some of the most important caterpillar pests of field crops, forests, and fruit and nut trees are attacked by *Trichogramma* wasps. However, in most crop production systems, the number of caterpillar eggs destroyed by native populations of *Trichogramma* is not sufficient to prevent the pest from reaching damaging levels. Recognizing the potential of *Trichogramma* species as biological control agents, entomologists in the early 1900s began to mass rear *Trichogramma* for insect control. Although a small commercial production of *Trichogramma* eventually developed in the U.S., insect control research and commercial efforts focused on the development of chemical pesticides following the discovery of DDT. This was not the case in the Soviet Union and China, both of which developed programs to control several crop pests with *Trichogramma*. In these countries, insectaries were less expensive and less sophisticated than production facilities for synthetic insecticides, and could be located on farms where labor was inexpensive and readily available. Also, control standards were not as stringent, and releasing *Trichogramma* was often better than no control at all (King 1993).

B. thuringiensis was first discovered in 1902 by Japanese biologist Shigetane Ishiwatari. In 1911, *B. thuringiensis* was rediscovered in Germany by Ernst Berliner, who isolated it as the cause of a disease called Schlaffsucht in flour moth caterpillars. Roh *et al.* (2007) reported the presence of a plasmid in a strain of *B. thuringiensis* and suggested the plasmid's involvement in endospore and crystal formation. *B. thuringiensis* is closely related to *B. cereus*, a soil bacterium, and *B. anthracis*, the cause of anthrax: the three organisms differ mainly in their plasmids. Like other members of the genus, all three are aerobes capable of producing endospores. Upon sporulation, *B. thuringiensis* forms crystals of proteinaceous insecticidal δ-endotoxins (called crystal proteins or Cry proteins), which are encoded by cry genes in most strains of *B.*

thuringiensis the cry genes is located on the plasmid. Cry toxins have specific activities against insect species of the orders Lepidoptera (moths and butterflies), Diptera (flies and mosquitoes), Coleoptera (beetles), Hymenoptera (wasps, bees, ants and sawflies) and nematodes. Thus, *B. thuringiensis* serves as an important reservoir of Cry toxins for production of biological insecticides and insect-resistant genetically modified crops. When insects ingest toxin crystals, the alkaline pH of their digestive tract activates the toxin. Cry inserts into the insect gut cell membrane, forming a pore. The pore results cell paralysis and eventual death of the insect.

Patel and Vyas (1999) reported that the compatibility of *Bt*. subsp. *kurstaki* (as Cutlass) with cypermethrin was studied against *E. vittella* and *S. litura*. Laboratory tests were carried out to determine the toxicity of the mixtures to the insects by feeding larvae okra pod slices (*E. vittella*) and castor leaves (*S. litura*) dipped in mixtures of insecticides at different concentrations. *Bt*. subsp. *kurstaki* was less effective against *S. litura* than *E. vittella*. It is suggested that *Bt*. subsp. *kurstaki* was compatible with cypermethrin.

2.3.3. Botanical management

The highest reduction of brinjal shoot and fruit borer infestation was found in the plots treated by neem oil and it was the most effective and these results were supported by Rahman *et al.* (2009).

Chatterjee *et al.* (2009) revealed that the lowest mean shoots as well as fruit infestation of brinjal (7.47 and 9.88%) was recorded in the plots treated with spinosad 2.5 SC (50 g a.i. ha^{-1}).

Tracer 45 SC could be considered as the most effective insecticide against BSFB in reducing shoot infestation in winter, while Proclaim 5 SG, Bactoil and Nimbicidene 0.03 EC could be moderately effective in both seasons. Helicide showed moderate effectiveness in winter season and less effectiveness in summer season while Necstar 50 EC and Boster 10 EC both showed less effectiveness in both seasons. Adiroubane and Raghuraman (2006) reported that the percent reduction of shoot damage ranged between 84.36 to 93.82 in case of Spinosad and 75.41 to 85.38 in Carbaryl + Wettable sulphur.

Patra *et al.* (2009) found the the lowest mean shoot as well as fruit infestation (7.47 and 9.88 %) in the plots treated with spinosad 2.5 SC (50 g ai ha^{-1}) followed by indoxacarb 14.5 SC 50 g ai ha^{-1} (8.89 and 13.13%) and emamectin benzoate 5 SG 15 g ai ha^{-1} (10.95 and 16.66%), respectively in a field experiment. The mean percent fruit infestation was the lowest (9.88%) in the plots treated with spinosad 2.5 SC followed by indoxacarb 14.5 SC (13.13%), emamectin benzoate 5 SG (16.66%) under field condition was reported by Patra *et al.* (2009).

Jat and Preek (2001) and Misra (1993) reported that Nimbicidene was the least effective insecticide in controlling the BSFB and resulted in the lowest yield but Srinibvasan *et al.* (1998) reported that nimbicidene provided higher yield (13.02 t/ha) than endosulfan.

The less effectiveness of Nimbicidene 0.03 EC was reported by Latif (2007), which was similar to the present study. He recorded 4.31% shoot infestation in the plots treated with Nimbicidene 0.03 EC while it was 7.01% in untreated control plots.

Puranik *et al.* (2002) reported minimum shoot (1.56%) as well as fruit (11.78%) infestation and maximum yield of marketable fruits (196.96 q/ha) when five sprays of Dipel 8L(Bt) @ 0.2 percent at 10 days interval were applied and proved to be the most effective treatment. The lower effectiveness of Helicide was in accordance with the finding of the study of Ghimire *et al.* (2007). He recorded higher fruit infestation both in terms of number and weight with NPV+Margosom (34.51±1.76 and 31.62±2.64%) which was (42.30 ± 4.56 and 43.57 ±8.9%) with untreated control, respectively.

The application of Tracer 45 SC performed the best in ensuring higher healthy fruit yield as well as total fruit yield of brinjal in both winter and summer seasons. Awal *et al.* (2014) found that Tracer 45 SC, Bactoil, Proclaim-5 SG demonstrated significantly higher mortality against 4th instar larvae of BSFB.

Jat and Preek (2001) and Misra (1993) reported that Nimbicidene was the least effective insecticide in controlling the BSFB and resulted in the lowest yield but Srinibvasan *et al.* (1998) reported that Nimbicidene provided higher yield (13.02 t/ha) than Endosulfan. Bactoil and Tracer 45 SC were relatively safe for natural enemies and therefore would be fit well into integrated pest management (IPM) against BSFB of brinjal crop (Awal *et al.* 2015).

Pareet (2006) found spinosad (Tracer 240SC) and emamectin benzoate (Timer 1.9EC) to be effective up to last harvest in reducing brinjal fruit borer damage. Deshmukh and Bhamare (2006), Adiroubane and Raghuraman (2008) and Aprana and Dethe (2012) found that spinosad (Tracer 240SC) was effective in controlling BSFB on brinjal.

According to Kodandaram *et al.* (2010) chlorantran iliprole was effective at a lower dose of 15-20 g ai/ha against brinjal shoot and fruit borer.

2.3.4. Resistant varieties

Resistance or susceptible of brinjal verities/lines to shoot and fruit borer seems to be related with some anatomical characters. Varities/Lines having thick cuticle, broad and thick collenchymatous area (hypodermis), compact parenchyma cells in the cortical tissue. Small area in the cortical tissues, more vascular bundles with narrower spaces in the interfacicular region, and compact arrangements of vascular tissue with lignifice cell as and small pith were the main characterisitics of resistant or tolerant varieties. On the other hand, thinner cuticule and cholenchymatous area (hypodermis), loose paranchyma cells in the cortical region, larger spaces between vascular bundles i.e., interfasicular region and large pith, a smaller number of trichomes, soft perenchymatous cells in the interfasicular region, might be responsible for the susceptibility to brinjal shoot and fruit borer (Hossain *et al.* 2002a).

Chlorophyll

Hossain *et al.* (2002a) carried out an experiment on the chlorophyll contents of brinjal leaf and its relation to the resistance and susceptibility to brinjal shoot and fruit borer, *L. orbonalis*. They observed that the lowest amount of chlorophyll a and chlorophyll b present in the variety Nayan Kajal and Laffa whereas the highest amount of chlorophyll a and chlorophyll b present in the variety BLO 101 and BLO 81, respectively. They also observed that the amount of chlorophyll b content was positively correlated with brinjal shoot and fruit borer infestation.

Moisture

Prodhan *et al.* (2009) evaluated moisture content of brinjal shoot and fruit of twenty different varieties/lines were estimated to find out the relationship between the infestation rate of brinjal shoot and fruit borer, *L. orbonalis* and the moisture content of brinjal shoot and fruit. The highest level of shoot moisture (91.97%) and fruit moisture (95.89%) Were recorded in the line BLO 72 and the lowest level of shoot moisture (81.65%) and fruit moisture (89.88%) in the variety brinjal. Brinjal shoot infestation was found to be positively correlated with shoot moisture (0.701) and fruit infestation was also positively correlated with fruit moisture (0.695).

Susceptibility

Yadav *et al.* (2003) conducted varietal screening of brinjal shoot and fruit borer (*L. orbonalis*). Ten aubergine cultivars were screened for their resistance against the shoot and fruit borer (*L. orbonalis*). All of the cultivars screened were susceptible to the pest.

Thirteen *Solanum* spp. genotypes and 30 F1 crosses of *S. melongena* were evaluated for resistance to *L. orbonalis* during February – October, 2000 under field conditions in Palampur, Himachal Pradesh, India. Arka Keshva was found resistant to the pest. Four genotypes and 11 F1 crosses were also found resistant to fruit infestation, recording 2.75-10.00% fruit damage. Six lines, Pusa Anupam, Punjab Barsati, SM 6-7, SM-141, CHES-243 and DBL V-4, with 17 F1 crosses were identified as fairly resistant. It was observed that attack of *L. orbonalis* was comparatively less fruits with tightly arranged seeds in the mesocarp (Anon. 2000).

Shoot and fruit infestation

Kumar and Shukla (2002) conducted an experiment during the Kharif season to investigate the varietal preference of *L. orbonalis* on aubergine. Twelve aubergine cultivars were used. A weekly record of *L. orbonalis* on each cultivar throughout the season was maintained by calculating the percentage of infested fruits on the basis of damaged and total fruit number at each picking.

Sridhar *et al.* (2001) evaluated brinjal (*Solanum* spp.) germplasm against shoot and fruit borer, *L. orbonalis*. Fifty-four brinjal (aubergine) germplasm, including five wild species and some F_1 crosses were screened for resistance to *L. orbonalis*, during 1999-2000, under field conditions in Bhubaneswar, Orissa, India. None of the cultivated or wild species of brinjal was found resistant to this pest. Three wild species, i.e. *Solanum khasianum*, *S. viarum* and *S. incanum*, were found to be tolerant from fruit infestation (0.5-10.0%). Among the cultivated lines, CHB-103, 187 and 259 were identified as fairly tolerant. Among the Brinjal groups, it was observed that in genotypes with relatively long fruits and tightly arranged seeds, the attack of *L. orbonalis* was less.

Singh and Singh (2001) screened 20 brinjal (*S. melongena* L.) cultivars against shoot and fruit borer (*L. orbonalis* Guen.) in a field experiment during the Kharif season of 1994 and 1995, Meghalaya, India. None of the cultivars was resistance to the pest, but three, five and eight cultivars were highly tolerant, tolerant and moderately tolerant, respectively. Eleven and two cultivars were susceptible and highly susceptible, respectively. Cultivar Kuchia (HRS-4) was the most tolerant cultivar, followed by Pithoria and Lata Begun.

The present findings of screening are conformity with the results of many researchers such as Choudhary *et al.* (2015) who investigated the relative response of different varieties against *L. orbonalis* under field conditions and found the infestation ranged in between 1.62 to 47.28 per cent, while the variety Krishna recorded infestation of 5.34 per cent, however, Pune Kateri and Phule Haritha recording 18.89 and 25.71 per cent damage respectively by shoot and fruit borer.

The infestation range of 8 to 28.60 percent and hybrid Swetha recorded infestation of 8.70 percent and highest fruit damage in Bejo Sheetal (48.4%) revealed by Elanchezhyan *et al.* (2008) which partially in line with present findings however cultivar Swetha was more infested during present investigation. Arka Keshav variety manifested mean fruit infestation of 37.14 per cent as reported by Umamahesh *et al.* (2018), which partially in conformity with the result of the present investigation.

Devi *et al.* (2015) observed minimum mean infestation in fruits of the genotype, Panjab Sadabahar (7.18%), 2010/BRLVAR-3 (9.54%), 2010/BRLVAR-1 (5.20%), 2010/BRLVAR-4 (5.28%), while maximum mean infestation in fruits (weight basis) recorded in Swarna mani (35.58%).

Thakare *et al.* (2021) conducted a field experiment on screening of 22 desirable genotypes/varieties of brinjal was carried out to evaluate their comparative performance against brinjal shoot and fruit borer *L. orbonalis*, during Kharif 2017-2018. The significantly the lowest shoot infestation of 0.89% was recorded in the cultivar, Susa local, followed by genotypes AKB-46, AKB-62, and Jayant which manifested shoot infestation of 1.92% 1.99%, and 2.04%, respectively. The lowest fruit infestation on a weight basis of 4.89 per cent was manifested in local cultivar Susa Local, on par with genotype AKB-46 (8.07%). While the lowest number basis fruit infestation of 4.52% reported in local cultivar Susa Local, par with Pune Kateri (8.38%). These genotypes would be of immense use in the breeding program for the development of resistant variety against *L. orbonalis*.

Mannan *et al.* (2003) conducted an experiment was carried out with 24 brinjal varieties at the Regional Agricultural Researh Station, Jamalpur Bangladesh to find the suitable brinjal variety against brinjal shoot and fruit borer (BSFB), *L. orbonalis* Guen. Both in number and weight the brinjal varieties Jumki-1 and Jumki-2 were highly resistant (HR), Islampuri-3, BL-34 and Muktakeshi were fairly resistant (FR), Singnath long and Singnath-4 were tolerant to brinjal shoot and fruit borer. The susceptible varieties were Islampuri-1 and IRRI begoon-1. Singnath-3 and Muktakeshi gave the highest yield from three years study and the lowest was obtained from Jumki although it was resistant to BSFB.

Sultana *et al.* (2018) conducted a study to find out the best variety of brinjal having resistance to BSFB. The varieties were V_1=BARI begun-1, V_2=BARI begun-4, V_3=BARI begun-5, V_4=BARI begun-6, V_5=BARI begun-7, V_6=BARI begun-8, V_7=BARI begun-9, V_8=BARI begun-10, V_9=Makra, V_{10}=Muktokashi, V_{11}=Lalita, V_{12}=Hazra, V_{13}=Chaga. Data were collected on total number of shoots, total number of infested shoot, percentage of shoot damage, percentage of shoot infestation reduction, numbers of larvae per infested shoot, total number of fruit, percentage of fruit damage, percentage of fruit infestation reduction, numbers of larvae per infested fruit. Results have shown that the minimum shoot infestation was found in BARI begun-6 (29.60%, 32.40%, 29.86% and 29.38%, respectively at four different stages of eggplant). Percent of fruit infestation was minimum in V_4 (BARI begun-6) (25.16%, 27.42% and 25.40% at three stages, respectively).

The number of healthy shoots plant-1 varied from variety to variety and shoot infestation was less observed than fruit initiation. It was probably due to the availability of fruit in the field and BSFB prefer fruits over the shoots (Choudhury *et al.* 2019). Production of the higher and lower number of healthy fruits plot^{-1} of different genotypes was probably due to the hereditary traits of individual variety and also some environmental factors especially soil nutrition, temperature, and pest management approaches.

Yadav *et al.* (2002) opined that the highest coefficient of variation coupled with moderate to high genetic advance and high heritability for fruits plant^{-1} which was in agreement with the present findings.

The highest number (118.66) of infested fruits plot^{-1} was harvested from BARI Begun-8. This might be due to a smaller number of hairs and prickles, its less density, erectness and the higher number of succulent leaves. Ishaque and Chaudhury (1983) found that the susceptible variety of brinjal had a larger leaf area.

Ali *et al.* (1994) studied morphological characters of plant, leaf, and fruits of 28 brinjal varieties/lines (entries) for their antixenosis against the brinjal shoot and fruit borer. They observed that small-sized fruits, ovals, slightly long, intermediate long and long shaped fruits with purple and greenish-white to green colored fruits showed lower percent of fruit infestation than those with the larger size, round-shaped and purple black and black colored fruits. Malik *et al.* (1986) suggested that lines bearing thin fruits with shorts, small calyx, and thin shoots were tolerant to *L. orbonalis*.

Devi *et al.* (2014) found a maximum fruit length of 21 cm in variety 2010/BRLVAR-1 which is in disagreement with the present results and Lakshman *et al.* (2015) reported the fruit length ranged from 8.61 to 21.64 cm among the twenty-nine tested genotypes of brinjal.

Lakshman *et al.* (2015) reported that mean fruit girth ranged from 4.33 to 9.90 cm among all twenty-nine tested genotypes. In maximum genotypes, the infestation level by BSFB on shoots and fruits increased with the increase in girth of fruit. The highest fruit girth (9.90 cm) was recorded in genotype 13/BRL VAR 4 with 5.7 and 20 percent shoot and fruit damage, respectively. Whereas it was the lowest (4.33 cm) in genotype Punjab Sadabahar with 1.2 percent shoot and 5.2 percent fruit damage.

According to Shri and Dhar (1995) the number of fruits plant-1 a varietal character that is largely governed by genetic and environmental factors.

Eggplant or brinjal (*S. melongena*) is a popular vegetable grown throughout Asia where it is attacked by brinjal fruit and shoot borer (BFSB) (*L. orbonalis*). Yield losses in

Bangladesh have been reported up to 86% and farmers rely primarily on frequent insecticide applications to reduce injury. Bangladesh has developed and released four brinjal varieties producing Cry1Ac (*Bt* brinjal) and is the first country to do so. We report on the first replicated field trials comparing four *Bt* brinjal varieties to their non-*Bt* isolines, with and without standard insecticide spray regimes. Results of the two-year study (2016–17) indicated *Bt* varieties had increased fruit production and minimal BFSB fruit infestation compared with their respective non-*Bt* isolines. Fruit infestation for *Bt* varieties varied from 0–2.27% in 2016, 0% in 2017, and was not significantly affected by the spray regime in either year. In contrast, fruit infestation in non-*Bt* lines reached 36.70% in 2016 and 45.51% in 2017, even with weekly spraying. An economic analysis revealed that all *Bt* lines had higher gross returns than their non-*Bt* isolines. The non-sprayed non-*Bt* isolines resulted in negative returns in most cases. Maximum fruit yield was obtained from sprayed plots compared to non-sprayed plots, indicating that other insects such as whiteflies, thrips and mites can reduce plant vigor and subsequent fruit weight. Statistically similar densities of non-target arthropods, including beneficial arthropods, were generally observed in both *Bt* and non-*Bt* varieties. An additional trial that focused on a single *Bt* variety and its isoline provided similar results on infestation levels, with and without sprays, and similarly demonstrated higher gross returns and no significant effects on non-target arthropods. Together, these studies indicate that the four *Bt* brinjal lines are extremely effective at controlling BFSB in Bangladesh without affecting other arthropods, and provide greater economic returns than their non-*Bt* isolines (Prodhan *et al.* 2018). However, maximum fruit yield was obtained from sprayed plots compared to non-sprayed plots, indicating that other insects such as whiteflies, thrips and mites can reduce plant vigor and subsequent fruit weight. Higher gross return was obtained from the *Bt* varieties over non-*Bt* isolines irrespective of spray regime; no spray non-*Bt* isolines resulted in a negative return in most cases. Statistically similar densities of non-target arthropods, including beneficial arthropods, were observed in both *Bt* and non-*Bt* varieties in most cases. An additional trial that focused on a single *Bt* variety and its isoline provided similar results on infestation levels, with and without sprays, and similarly demonstrated no effect on non-target arthropods. Together, these studies indicate that *Bt* brinjal is extremely effective at controlling BFSB in Bangladesh without affecting other arthropods. However, to achieve maximum yield of *Bt* brinjal other pest arthropods need to be managed (Naranjo *et al.* 2018).

As an alternative to intensive use of insecticides, the India-based Maharashtra Hybrid Seed Company (Mahyco) inserted the Cry1Ac gene, under the control of the constitutive 35S CaMV promoter, into eggplant (termed 'event' EE-1) to control feeding damage by ESFB. *Bt* eggplant demonstrated control of EFSB in contained greenhouse trials in India (Shelton *et al.* 2017). In late 2003, a partnership was formed between Mahyco, Cornell University, United States Agency for International Development (USAID), and public sector partners in India, Bangladesh, and the Philippines under the Agricultural Biotechnology Support Project II (Shelton *et al*. 2017).

The results from Bangladesh are similar to those from studies conducted in the Philippines in which event EE-1, the same event used to create the four *Bt* brinjal varieties used in these studies, was incorporated into open pollinated lines and provided almost complete control of BFSB in different locations over three cropping periods (Hautea *et al.* 2016). Furthermore, additional ecological studies in the Philippines (Navasero *et al.* 2016) documented that many arthropod taxa are associated with *Bt* eggplants and their non-*Bt* comparators, but found few significant differences in seasonal mean densities of arthropod taxa between *Bt* and non-*Bt* eggplants when no insecticides were used.

The Philippine studies found no significant adverse impacts of *Bt* eggplants on species abundance, diversity and community dynamics, particularly for beneficial NTOs. Similarly, in the present study we did not find any differences in the arthropod communities in any *Bt* brinjal variety compared to its non-*Bt* isoline. This is not surprising because the ecological effect of Cry1Ac has been extensively studied and shown to have little to no effect on non-target organisms outside of the Lepidoptera (Shelton *et al.* 2016).

Cultivation of Bt brinjal demonstrated no undesirable non-target effects on other arthropods in the system, especially those beneficial organisms that contribute important ecosystem services like biological control in Bangladesh. Overall, careful stewardship will be critical to preserving this valuable pest control technology as adoption continues to increase from the more than 27,000 farmers who grew Bt brinjal in 2018 (Shelton *et al.* 2018).

2.3.5. Use pheromone traps

For infestation level

Cork *et al.* (2003) stated that open delta trap caught significantly greater numbers of *L. orbonalis* males than other traps tested by them at the canopy level (delta, open delta, water with plastic bottle and sleeve trap). However, the authors revealed that open traps with water were more efficient in trapping adult male moths as water prevents the moths from escaping. Apart from these, Nandihalli *et al.* (1991) and Raj *et al.* (2000) suggested that sleeve and funnel traps were superior in catching *Helicoverpa armigera*. Similarly, Naik *et al.* (1993) noticed that sleeve and ICRISAT funnel traps were found better than sticky traps in catching *H. armigera*.

Although there were few references (Andagopal *et al.* 2010) to prove the efficacy of Wota-T trap, Cork *et al.* (2003) mentioned that the open trap with water performed better in capturing the *L. orbonalis* moths. The Wota-T trap was an open typed trap and contained water hence the findings of present study could be evidenced by the study of Andagopal *et al.* (2010) and Cork *et al.* (2003).

The eco-friendly insect-pest management consisting mass trapping through sex pheromone trap in different experiment field (Agronomy farm and Farmer's field) reported higher fruit yield with the lowest fruit damage compare to control area whereas, Farmers' field reported highest yield (395.12 q/ha) and the lowest shoot damage (8.42%) and fruit damage (6.51% and 6.29%) on number basis and weight basis, respectively. There was highly significant positive association between moth catches and shoot damage as well as with fruit damage from Agronomy farm and Farmers' field, respectively. The highest marketable fruit yield (395.12 q/ha) obtained in Farmers' field with higher per cent increase over control in both number (19.66%) and weight (22.67%) basis, respectively (Das *et al.* 2014).

Trapping method

Sateesh kumar *et al.* (2009) stated that a dose of 2 mg per dispenser is considered sufficient for the purpose of monitoring the pest incidence of *L. orbonalis* and also cost effectiveness. The trap catches were highest in those traps with lures changed every 21 days, while changes made every 45th and 60th day were also promising but only up to 21 days and thereafter declined gradually indicating that irrespective of the changing frequency, the test lures were found to be effective up to 21 days. These results are in conformity with those of Loganathan *et al.* (1999), Patil and Mamadapur (1996) and Kumari and Reddy (1992) who reported that lures must be changed in three weeks.

Position of trap setting

The effect of pheromone trap positions observed in the present study and may be attributed to the easy entrance of the lures and traps, when they are placed at the canopy. It is to be noted that the adult moths of BSFB are trapped in the pheromone trap only at the night because of their nocturnal behavior, and the traps below the canopy are subject to physical barrier due to crop canopy. Moreover, the placement of the traps in the center of the field provided a uniform distribution of the traps throughout the crop field, which facilitate uniform and more attraction of the BSFB moths to the trap. Such findings have resemblance with the findings of many other researchers. The highest catch of adult BSFB was observed at plant canopy resulting in minimum shoot infestation (Alam *et al.* 2003). Brinjal has a relatively open canopy that might allow sustained flight of the pest adults inside and outside the crop (Mason *et al.* 1997). IPM is compatible and potential to be adopted on a broad scale and to provide a low-cost management strategy (Gahukar 2000; Hillocks 1995).

2.3.6. Chemical management

Awal *et al*. (2017) conducted an experiment out in two consecutive cropping seasons to evaluate the effectiveness of seven insecticides against brinjal shoot and fruit borer (BSFB) in the experimental farm of the Department of Entomology, BSMRAU, Bangladesh. Tracer 45 SC was found to be highly effective in reducing 88.22 % and 84.41 % shoot infestation over control during summer and winter, respectively followed by Proclaim 5 SG (74.12 % in summer and 64.36 % in winter). The highest number of healthy fruits per plant (22.38 in summer and 35.69 in winter, respectively) and the highest yield of eggplant per hectare (19.94 t/ha in summer and 24.79 t/ha in winter) were obtained from Tracer 45 SC treated plots. Therefore, it may be concluded that Tracer 45 SC (Spinosad) @ 0.4 ml/L could be the most effective insecticide in controlling brinjal shoot and fruit borer and also in getting highest yield of eggplant.

Radhika *et al.* (1997) found that application of 0.1% triazophos on need basis (when > 20% of the fruits was infested by the pest) produced the highest fruit yield and the highest return. Application of carbaryl, cartap hydrochloride [cartap], endosulfan, diflubenzuron, azadirachtin and chlorpyrifos at 1.0, 0.5, 0.7, 0.07, 0.075 and 0.4 kg a.i. per ha at 30, 45, 60, 75 and 90 days after transplanting (DAT), respectively, reduced shoot and fruit infestation, and gave the highest fruit yield (196.61 quintal per ha) and benefit cost ratio (3.76:1).

Mishra and Siddiqi (2004) found that triazophos gave the lowest average fruit borer incidence (14.36%) and the highest average fruit yield (20.75 q per ha).

Deshmukh *et al.* (2006), amongst newer insecticides, cartap hydrochloride 50 SP at 0.1% was found the most effective in reducing shoot infestation (4.20%) and fruit infestation (23.72% on number basis and 25.30% on weight basis) and in increasing aubergine fruit yield (78.73 q per ha). Sharma *et al.* (2009) found that the main crop, border cropped with either baby corn or radish or guar along with two foliar sprays of spinosad @ 75 g a.i. per ha was very effective in minimizing the fruit borer incidence. Brinjal bordered with radish followed by foliar spray of thiamethoxam @ 20 g a.i. per ha followed by abamectin @ 15 g a.i. per ha and emamectin benzoate @ l0g a.i. per ha gave highest yield viz., 17.128 MT per ha and 26.350 MT per ha, respectively.

Dutta *et al.* (2011) revealed that proclaim 5 SG (emamectin benzoate) showed moderate level of efficacy providing 62.8% reduction of BSFB population over control it is concluded that this pest might have developed resistance against the tested insecticides.

Nenavati and Kumar (2014) reported chlorpyriphos was the most effective in the reduction of damage of shoot and fruit infestation. However, shoot and fruit infestation was brought down and marketable yield increased to some extent, when the chlorpyriphos combined with other insecticides. The results revealed that chlorpyriphos was found to be most economical, resulting in minimum shoot and fruit infestation Sharma *et al.* (2012).

Islam *et al.* (2004) found that fenvalerate (0.02%) was the best treatment followed by carbofuran 3 G at 0.5 kg a.i per ha, removal and destruction of infested plant parts, neem oil at 0.2% concentration, neem leaf extract at 1:1 ratio and dipel at 0.15 per cent concentration.

Studied bioefficacy of some botanical and their combination with chemicals and (Yogi and Kumar 2010) evaluated some chemical insecticides against (*Leucinodes orbonalis*) from Allahabad.

Misra (1989) studied the bio-efficacy of some insecticides against the pest complex of okra. The author reported that percent shoot infestation in insecticide treated plots varied from 1.74-10.03% compared to 15.23% in untreated control plots.

Kabir *et al.* (1996) evaluated several insecticides (Ralothrin 10 EC, Sunfuran 36 EC, Fenom 10 EC, Selecron 50 EC, Fastac 2 EC, Decis 2.5 EC, Arrivo 10 EC, Shobicron 4.25 EC, Cymbush 10 EC, Ripcord 10 EC, Nogos 10 EC) against BSFB over three consecutive seasons at Gazipur and Jessore district of Bangladesh and reported that none of the tested insecticides had significant effect in reducing the pest population.

Sabry *et al.* (2014); Hamdy and Sayed (2013); Chatterjee and Mondal (2012); Shah *et al.* (2012); Anil and Sharma (2010); Sharma and Sharma (2010) and Wankhede and Kale (2010) reported that emamectin benzoate (Timer 1.9EC) was the most effective insecticide in reducing BSFB infestation and increasing marketable fruit yield.

2.3.7. Natural enemies

Natural enemy	**Type**	**Life stages**
Bacillus thuringiensis kurstaki	Pathogen	
Bacillus thuringiensis thuringiensis	Pathogen	
Baculovirus	Pathogen	Arthropods|Larvae
Bracon	Parasite	Arthropods|Larvae
Bracon brevicornis	Parasite	
Campyloneura	Parasite	Arthropods|Larvae
Cochliobolus spicifer	Pathogen	
Eriborus argenteopilosus	Parasite	
Gibberella fujikuroi	Pathogen	
Gibberella sacchari	Pathogen	Arthropods|Larvae
Itamoplex	Parasite	Arthropods|Pupae

Natural enemy	Type	Life stages
Nucleopolyhedrosis virus	Pathogen	
Phanerotoma	Parasite	Arthropods|Larvae
Pseudoperichaeta	Parasite	Arthropods|Larvae
Trathala	Parasite	Arthropods|Larvae
Trathala flavoorbitalis	Parasite	Eggs
Trichogramma chilonis	Parasite	

Seventy-two genotypes of okra were screened by Kashyap and Verma (1983) in Hariana, India against *Earias* spp. under field condition. Pest infestation and fruit yield were recorded on the basis both of numbers and weights. Less than 10% (on a weight basis) infestation was obtained in Parkins long green, *Clemson spineless,* White snow and Sel round cultivars compared to more than 50% in IC 12933, wild Bhindi and RI. The rest of the genotypes were intermediate.

2.3.8. IPM

Singh *et al.* (2009) was observed that profenofos @ 0.1% and spinosad @ 0.01% were most effective in reduction of shoot infestation of *L. orbonalis* besides recording higher brinjal fruit yield. Among the nine treatments tested, profenofos was the most effective followed by spinosad individually and their combinations in reducing the population as well as in giving higher yield. Profenofos 50 EC @ 1000, 1500, 2000, 4000 ml per ha, Endosulfan 35 EC @ 1200 ml per ha, Chlorpyriphos 20 EC @ 1250 ml per ha and carbaryl 50 WP (4 g per litre) gave significant reduction of brinjal shoot and fruit borer as compared to control. Profenofos @ 1000 ml per ha proved effective in reducing incidence of the pest and it was almost on par with other higher dosages. The yield data also showed that profenofos recorded higher yield compared to other insecticides (Kumar and Devappa 2006).

Awal *et al*. (2014) observed that the mortality of Tracer 45 SC, Bactoil, Proclaim 5 SG, and BSFB larvae was significantly higher than that of fourth instar BSFB larvae. Bactoil and Tracer 45 SC are relatively harmless to natural enemies, so they were terribly appropriate for the integrated pest management (IPM) of BSFB (Awal *et al*. 2015).

Chaterjee (2009) showed that trap+ mechanical removal + application of botanicals was the only module for the management of fruit and shoot borer with considerable yield increment of the crop. A complete of 54.08 and 41. 01 moth was captured at intervals the module of spraying Ripcord 10EC @ 1.0 ml L^{-1} water at 10 days an interval+pheromone trap and spraying spinosad 45SC @ 0.4 ml L^{-1} water at 10 days an interval+nappy trap, respectively (Faruq *et al.* 2021).

Alam *et al.* (2003) and Cork *et al.* (2003) found that biological pest management in Asia is currently exchange pesticides, that is in step with the results of Satpathy *et al.* (2005) applied IPM methods, specifically pruning and removing infected branches, removing perforated fruits, putting in 12 pheromone traps per hectare and reducing the discharge of *Telenomus chilonis* and therefore the use of pesticides.

Adiroubane and Raghuraman (2006) reported that the percent reduction of shoot damage ranged between 84.36 to 93.82 in case of Spinosad and 75.41 to 85.38 in Carbaryl + Wettable sulphur. Patra *et al.* (2009) found the lowest mean shoot as well as fruit infestation (7.47 and 9.88 %) in the plots treated with Spinosad 2.5 SC (50 g ai ha^{-1}) followed by indoxacarb 14.5 SC 50 g ai ha^{-1} (8.89 and 13.13%) and emamectin benzoate 5 SG 15 g ai ha^{-1} (10.95 and 16.66%), respectively in a field experiment. The mean percent fruit infestation was the lowest (9.88%) in the plots treated with spinosad 2.5 SC followed by indoxacarb 14.5 SC (13.13%), emamectin benzoate 5 SG (16.66%) under field condition was reported by Patra *et al.* 2009. Kabir *et al.* (1996) evaluated several insecticides (Ralothrin 10 EC, Sunfuran 36 EC, Fenom 10 EC, Selecron 50 EC, Fastac 2 EC, Decis 2.5 EC, Arrivo 10 EC, Shobicron 4.25 EC, Cymbush 10 EC, Ripcord 10 EC, Nogos 10 EC) against BSFB over three consecutive seasons at Gazipur and Jessore district of Bangladesh and reported that none of the tested insecticides had significant effect in reducing the pest population. The less effectiveness of Nimbicidene 0.03 EC was reported by Latif (2007), which was similar to the present study. He recorded 4.31% shoot infestation in the plots treated with Nimbicidene 0.03 EC while it was 7.01% in untreated control plots. Puranik *et al*. (2002) reported minimum shoot (1.56%) as well as fruit (11.78%) infestation and maximum yield of marketable fruits (196.96 q/ha) when five sprays of Dipel 8L(*Bt*) @ 0.2 percent at 10 days interval were applied and proved to be the most effective treatment. The lower effectiveness of Helicide was in accordance with the finding of the study of Ghimire *et al.* (2007). He recorded, higher fruit infestation both in terms of number and weight with NPV+Margosom (34.51±1.76 and 31.62±2.64%) which was (42.30 ± 4.56 and 43.57 ± 8.9%) with untreated control, respectively.

Mishra *et al.* (2007), granular application of carbofuran @ 1.5 kg a.i. per ha at 10 days of planting followed by spray of triazophos @ 0.5 kg a.i. per ha, cypermethrin @ 0.150 kg a.i. per ha, azadirachtin @1500 ppm per ha and imidacloprid @ 0.025 kg a.i. per ha in sequence at 10-15 days interval after 40 days of planting was the most effective schedule in managing brinjal shoot and fruit borer.

Mandai *et al.* (2007) reported that combinations of bio-pesticides and eco-friendly chemicals were field evaluated in Samastipur, Bihar, India, during the summer seasons of 2000 and 2001 against the spider mite (*T. neocaledonicus*) for sustainable production of okra. The treatments comprised: *Bacillus thuringiensis* (*Bt.*) + endosulfan 35 EC (500 g + 250 g/ha), *Bt.*+acephate 75 SP (500 g + 300 g/ha), neem [*Azadirachta indica*] cake+neem oil+endosulfan 35 EC (200 kg+0.5 l+250 g/ha), N:P:K (69:72:90 kg/ha), endosulfan 35 EC (0.5 kg/ha), acephate 75 SP (300 g/ha), neem cake (200 kg/ha), neem oil (0.5 l/ha), and control. The pooled data revealed that neem cake+neem oil+endosulfan was the most effective, exhibiting the minimum mite population (6.8/leaf) and proved to be the best. It was followed by *Bt.*+endosulfan (9.8/leaf) and *Bt.*+acephate (11.9/leaf), which was at par with each other. The sole treatments, i.e. N:P:K, endosulfan, acephate, neem cake and neem oil, were also effective against the mite and showed population of 18.2, 19.3, 15.7, 23.8 and 28.8 per leaf, respectively, compared to the control (36.9/leaf).

Yadav *et al.* (2008) reported that a field experiment was conducted in Kanpur, Uttar Pradesh, India, during the 2005 and 2006 Kharif seasons, to determine the yield and cost benefit ratio of okra cv. Azad bhindi-1 including economics of IPM modules against okra pests. The treatments comprised: 1.0 kg *Bacillus thuringiensis*/ha; 4.0 litres Neemarin/ha; 2.0 litres endosulfan/ha; 3 cards *Trichogramma*/ha. Maximum economic return was obtained with the application of *B. thuringiensis* followed by endosulfan; the return of Rs. 5888.0 was obtained in Bt. alone, Rs. 16 726.50 in Neemarin - *Trichogramma*; Rs. 21 151.36 in *Bt.* - Neemarin - *Trichogramma* spraying schedule. In overall treatments of combination, *Bt*. - Neemarin - *Trichogramma* and *Bt*. - Neemarin - endosulfan - *Trichogramma* module gave the highest economic return (Rs. 231 151.36 and Rs. 210 315.00). An increase in yield up to 15.8% were obtained in *Bt*. alone; 29.34% in *Bt*. - *Trichogramma*; 35.0% in Neemarin - endosulfan - *Trichogramma* and 37.5% in *Bt*. - Neemarin - endosulfan - *Trichogramma* module.

The application of endosulfan - *Trichogramma* followed by application of Neemarin - *Trichogramma* recorded the highest cost-benefit ratio of 1:15.3 and 1:13.3, respectively.

Mandal *et al.* (2006) reported that the efficacy of *Bacillus thuringiensis* (500 g/ha) applied alone or in combination with cartap (150 g/ha), acephate (300 g/ha), chlorpyrifos (250 g/ha), endosulfan (250 g/ha) and 0.5% Amrutguard in controlling pests infesting okra was determined in a field experiment conducted in Bihar, India during the summer of 2000-01. Treatment with *B. thuringiensis* in combination with endosulfan resulted in the lowest percentage of shoot infestation (9.10%) and percentage of fruit infestation by number (17.35%) and by weight (16.03%), as well as the highest marketable fruit yield (123.14 q/ha), net income (Rs. 13 635.50/ha) and cost benefit ratio (1:2.96).

Mandal *et al.* (2008) found that the treatment pheromone trap + shoot clipping + neem-based pesticide + removal of damaged fruits during harvesting was best for the management of BSFB. Anjali (2006) revealed that cypermethrin (0.007%) and carbaryl (0.02%) were at par with each other and were significantly superior to all other treatments in terms of percent shoot damage, fruit damage of BSFB on number and weight basis and on yield basis.

The integrated pest management (IPM) strategy for the control of *L. orbonalis* consists of resistant cultivars, sex pheromone, cultural, mechanical and biological control methods (Srinivasan and Babu 2000). Successful adoption of IPM in eggplant cultivation increase profits, protect the environment and improve public health (Alam *et al.* 2003). The profit margins and production area significantly increased, whereas pesticide use and labor requirement decreased for those farmers who adopted the IPM technology. But, the efforts to expand the *L. orbonalis.*

IPM technology to other regions of South and Southeast Asia are underway (Srinivasan 2009). Use of crop management practice in IPM model is easy method of pest management. The interaction of intercrop and antifeedant showed that coriander-intercropped eggplant along with foliar spray of Neemarin significantly reduced fruit damage (Satpathy and Mishra 2011).

Different researcher developed the different module of pest *L. orbonalis* management. Chakraborty and Sarkar (2011) found that integration of phytosanitation, mechanical control and prophylactic application of Neem Seed Kernel Extract (NSKE) exerted a satisfactory impact on the incidence and damage of *L. orbonalis*. Sanitation and destruction of alternate host reduces the pest damage to fruit if such practice is coupled with other community wide means to reduce immigration of pest adults into the area (Alam *et al.* 2003).

Use of pheromone and microbial is compatible strategy in pest management. Krishnamoorthy (2012) indicated that integration of egg parasitoid release with NPV, Neem and pheromone trap has been proved as possible in IPM modules. Out of different module tested by Dutta *et al.* (2011), the module with three different components, viz. pheromone trap, mechanical control and application of Peak Neem (neem-based insecticide) was found the best in reduction of shoot damage, fruit damage and yield increment followed by pheromone trap + Peak Neem in terms of shoot damage, farmers practices in terms fruit damage and pheromone trap + Peak Neem in terms of yield increment. The integration of *T. chilonis* and sanitation reduced infestation of *L. orbonalis* by 15 to 35 percent in the field and increased yields by 35-100 percent (Gonzales 1999).

Again, the use of insecticides based on different chemistry and with varying modes of action is an important component of an IPM strategy. Hence, insecticides continue to be an integral component of pest management programs due mainly to their effectiveness and simple use (Braham and Hajji 2009).

Use of pesticide was not suggested at first hand but judicious use as last option of pest management was suggested globally. Chakraborty (2012) demonstrated the efficient model of IPM based on yield. They are i) need-based application Flubendiamide together with NSKE, NLE, deltamethrin + trizophos; ii) application of new molecule of Rynaxypyr, NLE, NSKE, Clorpyriphos; iii) NSKE, emamectin benzoate, NLE, clorpyriphos, Neem and Oil. The efficacy of first one is the highest and lowering on later.

The use practice of pesticides of different group was proved efficient by Abrol and Singh (2003) that endosulfan + deltamethrin (0.07%, 0.0025%) and endosulfan + fenvalerate (0.07% + 0.005%) were highly effective against *L. orbonalis* that recorded only 13.3 percent damage as compared to 69.8 percent in control. The combination of compatible tactics was always superior. Any single option, such as sole mechanical control, schedule spray of carbosulfan at 7 days interval or sole sex pheromone trap was inferior to any of other combined options and the combinations of options resulted lowest damage shoot/fruit compare to control. Thus, combination of three options produced with the highest yield of healthy fruits as well as maximum BCR (Rahman *et al.* 2009).

The model of IPM having shoot clipping with alternate spraying of Multineem and trizophos plus deltamethrin was given by Bhushan *et al.* (2011) with minimum shoot and fruit damage and maximum yield.

Sharma *et al.* (2012) reported that the treatment including pesticides and botanicals combined with cultural method lowered shoot/fruit damage and increased fruit yield. In addition, Latif *et al.* (2009) used the potash in IPM module suggesting that the application of flubendiamide at 5 percent level of fruit infestation in combination with mechanical control + potash @ 100 kg/ha + field sanitation for the management of *L. orbonalis*. Although various IPM strategies have been developed and promoted for vegetables, adoption remains low due to IPM's limited effectiveness in managing insect pests compared with chemical pesticides. Moreover, IPM has been promoted as a combination of techniques without giving due consideration to the compatibility of each component (Srinivasan 2012).

CHAPTER III

MATERIALS AND METHODS

A set of five experiments was conducted to achieve the objectives as designed for this research. The methods of each five experiments and materials for the experiments were presented in this chapter. The details of the methodology of the experiments are given below:

3.1. Experiments

Experiment-1: Cross-cutting issues of farmers' practices for the management of brinjal shoot and fruit borer in Bangladesh;

Experiment-2: Screening of commonly cultivated brinjal varieties against brinjal shoot and fruit borer;

Experiment-3: Efficiency of different pheromone traps and their setting positions for capturing adult moth of *Leucinodes orbonalis*;

Experiment-4: Effectiveness of botanicals and other non-chemical approaches against BSFB in comparison with chemical insecticides; and

Experiment-5: Development of IPM packages against BSFB for safe and hazard free brinjal production.

3.2. Methodology

Experiment 1: Cross-cutting issues of farmers' practices for the management of brinjal shoot and fruit borer in Bangladesh

Objectives

- To find out the pesticide usage pattern and its hazardous effects in the field of brinjal against BSFB;
- To identify the alternative approaches for eco-friendly management of BSFB under the field condition.

This sub-section covers the approach, strategy and design of the study; preparation of the study tools; implementation of the study including review of secondary documents, primary data collection through field visits and discussions, survey of relevant stakeholders, processing and analysis of the collected data.

The methodology was drawn in line with the objectives of the study. The suitable tools for survey had been developed on particular parameters in respect of perception of pesticide usage pattern, its judicious use for controlling brinjal shoot and fruit borer in field condition; knowledge about the residual toxicity and hazardous effect of pesticides; safety measures for pesticide application, hazards free management of BSFB; alternative approaches for controlling BSFB such as botanicals, non-chemical methods, resistant/tolerant brinjal variety(ies), pheromone traps, etc. The specific methodologies for different activities such as study design, review of secondary documents, field visits and field survey and discussion with the farmers, processing and analysis primary survey data were summarized in the following sub-headings:

3.2.1.1. Sources of data

The study was conducted to generate stipulated primary data. Prior to generation of primary data, the relevant secondary information on the brinjal shoot and fruit borer (BSFB) and its extent of damage, traditional management practices and their cross-cutting issues were reviewed meticulously. To develop the study instruments accurately and comparison with major indicators of the study, the secondary data were carefully scanned and had been collated according to the objectives of the study. For generating the desired primary data, the proposed sample study was conducted using an appropriate sampling design and a formatted questionnaire.

3.2.1.2. Study duration

The survey study was conducted during rabi season of 2016-17 aiming to find out the pesticide usage pattern and its hazardous effects in the field of brinjal against BSFB and identify the alternative approaches for eco-friendly management of BSFB in the field condition.

3.2.1.3. Study location

The survey study had been conducted from 10 upazila under five districts such as Jashore (Upazila: Keshabpur and Sadar), Dhaka (Upazila: Savar and Keraniganj), Cumilla (Upazila: Chandina and Barura, Narshingdi (Upazila: Raipura and Belabo) and Munshiganj (Upazila: Sadar and Tongibari) where brinjal is intensively grown.

Plate 1: Survey area depicted in Bangladesh map

3.2.1.4. Sample design

Two types of analysis were made to gather information about the study and those were quantitative and qualitative.

Quantitative survey

In order to ensure representativeness of the data and information, the sampling strategy followed in this study is delineated below:

The population under the study were constituted to assess the farmers' perception on the extent of damage caused by BSFB; commonly used management practices and their health hazard issues; as well as to provide suggestive measures for economically viable and eco-friendly management issues. Using 95% confidence level with 5% margin of error it was needed to obtain a representative sample size of farmers which was 310 for this study.

For such purpose a sound statistical formula without Finite Population Correction (FPC) recommended by Daniel (1999) was adopted to determine the appropriate sample size as follows:

$$n = \frac{Z^2 PQ}{e^2}$$

Where,

n = Sample size without finite population correction (FPC),

P = Proportion/Probability of success (if the prevalence is 50%, P=0.5),

Q = 1-P,

Z = Z statistic for a level of confidence,

e = Precision or allowable margin of error (if the precision is 5.6%, then e=0.056)

Assumptions:

Z = 1.96 (the value of the standard variation at 95% confidence level)

P = 0.5

Q = 0.5

e = 0.056 (allowable margin of error at 5.6%)

Therefore, using this formula, the sample size (n) for respective stakeholders had been calculated as follows:

$$n = \frac{(1.96)^2 \text{ x } 0.5 \text{ x } 0.5}{(0.055)^2}$$

= 3.8416*0.25/0.003136

= 0.9604/0.003136

= 306.

The sample size became 310 by using a figure for equal distribution of farmers to 10 sampled upazila instead of 306. The brinjal farmers were selected using simple random sampling technique.

However, in order to reach such respondents multi-stage random sampling procedure were adopted. At the first stage, five major brinjal growing districts were chosen under the study areas. According to the assumption, five (5) sampled districts namely Jashore, Dhaka, Narshingdi, Cumilla and Munshiganj were considered as area coverage. At the second stage, two major brinjal growing upazilas for each of five sampled districts were chosen. Thus, a total of 10 sample upazilas were selected. At the third stage, two unions from each of 10 upazilas were chosen. Then 3 agricultual blocks were chosen from each sample union at the fourth stage. At the final stage, 5 brinjal farmers were selected randomly from each sample agricultural block. Thus, the 310 sample farmers were distributed to the sample district, upazila, union and agricultural block proportionately. For the benefit of the distribution of all 310 sample farmers some adjustments were also done as shown in the table 3.1.

During the farmers' selection, unions and agricultural blocks were selected in consultation with the respective Upazila Agriculture Officer (UAO) and brinjal farmers were selected from each of the sampled agricultural block with the help of Sub-Assistant Agriculture Officer (SAAO) of the respective block. During the selection of field level officials of DAE for each upazila, Upazila Agriculture Officer (UAO) and Sub-Assistant Agriculture Officers (SAAO) were considered for collecting qualitative information.

Table 3.1. Area-wise sample distribution

District	Upazila	Union	No. of brinjal farmers	No. of pesticide dealers/traders	No. of Field level DAE officials
Jashore	Sadar	Chachra	15	1	0
		Basundia	16	0	1
	Keshabpur	Sagordari	15	1	0
		Pajia	16	0	1
Dhaka	Savar	Asulia	15	0	1
		Aminbazar	16	1	0
	Keraniganj	Taranagar	15	1	0
		Sakta	16	0	1
Narshingdi	Belabo	Amlab	15	0	1
		Narayanpur	16	1	0
	Raipura	Raipura	15	1	0
		Alipura	16	0	1
Cumilla	Chandina	Keran Khal	15	1	0
		Barera	16	0	1
	Barura	Uttar Deora	15	0	1
		Dakshin Bhabanipur	16	1	0
Munshiganj	Sadar	Rampal	15	1	0
		Bajra Jogini	16	0	1
	Tongibari	Panchgaon	15	0	1
		Kamarakhara	16	1	0
Total	**10**	**20**	**310**	**10**	**10**

3.2.1.5. Variables/indicators covered

The following variables were considered during development of questionnaire for data collection from the brinjal farmers.

1. **Demographic** **:** Name, Age, Sex
2. **Social** **:** Education, Profession and Experience
3. **Study related indicators**-

- Common cultivated brinjal varieties
- Problems faced during brinjal cultivation
- Kinds of insect pests attack in the brinjal field
- Extent of damage caused by insect pests in the brinjal field
- Yield loss caused by brinjal shoot and fruit borer (BSFB)
- Control measures practiced by the farmers against BSFB
- Kinds of insecticides applied for controlling BSFB
- Frequency of insecticides applied in brinjal field
- Time interval for application of insecticides in the field of brinjal
- Alternative methods other than chemical insecticides used for controlling BSFB
- General ideas about natural enemy killing, health and environmental hazardous issues due to application of insecticides

3.2.1.6. Development of study tools/questionnaire

The questionnaire (Appendix II) of the study was prepared based on the objectives and indicators determined for the survey study and methodologies. The study questionnaire was pre-tested in the study location and thereafter, it was finalized with due care to include appropriate questions for collection of necessary information from different levels and types of respondents to reflect the indicators relevant to the objectives of the study.

Plate 2: Brinjal field at Jashore district

Plate 3: Data collection from the brinjal farmer at Jahsore district

Plate 4: Data collection from the brinjal farmer at Dhaka district

Plate 5: Data collection from the brinjal farmer at Narshingdi district

Plate 6: Data collection from the brinjal farmer at Cumilla district

Plate 7: Data collection from the brinjal farmer at Munshiganj district

Some pictorial documents from the farmer fields

Plate 8: Infested brinjal fruit caused by BSFB

Plate 9: Insecticide application in the brinjal field

Plate 10: Insecticide's packet thrown in the brinjal field

Plate 11: Insecticide's packet thrown anywhere beside the field

Plate 12: Insecticidal residues on the brinjal leaves due to indiscriminate use of insecticide

Plate 13: Insecticidal residues on the brinjal leaves due to indiscriminate use of insecticide

3.2.1.7. Method of data collection

The face-to-face interviews of the sampled brinjal farmers were collected in the sampled locations and those are given below:

During data collection period, the researcher reached to a sample upazila and contacted with the respective Upazila Agricultural Officer (UAO), DAE. In consultation with the UAO, target unions and agricultural blocks were selected based on the cultivation of brinjal. The UAO also helped for introduction with respective Sub-Assistant Agricultual Officer (SAAO) and instructed the SAAOs to provide help the researcher to select the targeted brinjal farmers. At the block level, researcher find the targeted brinjal farmers and collected relevant information as per pre-designed questionnaire after building up a good raport with the farmers. After completion of the fill-up of one questionnaire, researcher moved to find one next brinjal farmer and subsequently filled-up the next questionnaire. Following the similar procedure researcher moved to another sampled upazila and completed the data collection from all 310 sample farmers.

3.2.1.8. Data Analysis

The filled-up questionnaires were coded according to the respective upazila and district. Then the entry of data was performed using SPSS 20.0 version computer package and accordingly frequency analysis was done to generate objective-wise desired information.

Experiment-2: Screening of commonly cultivated brinjal varieties against brinjal shoot and fruit borer

Objectives

- To identify the tolerant/resistant or least preferred brinjal varieties against BSFB;
- To assess the level of infestation of shoots and fruits of sample brinjal varieties against BSFB.

The present study of varietal performance of brinjal against brinjal shoot and fruit borer was carried out using 13 brinjal varieties. The materials and methods adopted in the study are discussed under the following sub-headings:

3.2.2.1. Experimental site and duration

The research work was carried out at the experimental field of Sher-e- Bangla Agricultural University (Appendix III), Dhaka during the period from October, 2016 to May, 2017 for the varietal performance of brinjal against brinjal shoot and fruit borer. The soil of the experimental site was well drained and moderate high (Appendix IV). The soil of the experimental plots is belonged to the agro ecological zone Madhupur Tract (AEZ-28).

3.2.2.2. Climate

The climate of the experimental site is sub-tropical characterized by moderate rainfall during April to May and sporadic during the rest of the year. During November to February, the temperature was less than the other months of the year and starts increasing after mid- march (Appendix V). The detail record of monthly total rainfalls, temperature, and humidity during the period of experiment were noted from the Bangladesh Meteorological Department (Climate Division), Agargaon, Dhaka.

3.2.2.3. Design of the experiment

The experiment was conducted in randomized complete block design (RCBD) with three replications.

3.2.2.4. Land preparation and layout

The experimental land was first opened with power tiller. Ploughed soil was then brought into desirable final tilt by four operations of ploughing followed by laddering and prepared the land with good tilth. The field layout was done in accordance with the design, immediately after land preparation (Appendix-VI). The good tilth main field was then divided into three main blocks considering 1 m block to block distance. Each block was sub-divided into 13 sub-plots for 13 brinjal varieties considering 2 m x 1.5 m plot size and 0.5 m plot to plot distance. The plots were then raised by 10 cm from the soil surface keeping the drain around the plots.

3.2.2.5. Manures, fertilizer and their methods of application

The experimental plots were fertilized at the rate of 15 T/ha, 250 kg/ha and 125 kg/ha, 5 kg/ha, 5 kg/ha of Cow dung, Urea, Triple Super Phosphate (TSP), Muriate of Potash (MoP), Gypsum and Boric Acid, respectively as per recommended dose of brinjal cultivation (BARC, 2018). The entire amount of cow dung was applied at first land preparation. TSP, half of Urea and MoP were applied at the time of final land preparation. The remaining half of the Urea and MoP were applied at two equal installments as top dressing. The first top dressing was done at 21 days after transplanting and second at the flowering stage of brinjal. Entire amount of boric acid and gypsum was applied as basal dose during final land preparation.

3.2.2.6. Materials used

Thirteen (13) brinjal varieties developed and released by Bangladesh Agricultural Research Institute (BARI) were cultivated in the experimental field to evaluate their performance against brinjal shoot and fruit borer. Each of the variety was treated as an individual treatment. The names of 13 brinjal varieties cultivated in the field and their source of collection are given below (Table 3.2):

Table 3.2. Treatment used under the experiment

Treatment	Name of variety	Source
V_1	BARI Bt Brinjal-1	BARI
V_2	BARI Bt Brinjal-2	BARI
V_3	BARI Bt Brinjal-3	BARI
V_4	BARI Bt Brinjal-4	BARI
V_5	BARI Begun-1 (Uttara)	BARI
V_6	BARI Begun-4 (Kajla)	BARI
V_7	BARI Begun-5 (Nayantara)	BARI
V_8	BARI Begun-6 (Ishurdi local)	BARI
V_9	BARI Begun-7 (Singnath)	BARI
V_{10}	BARI Begun-8	BARI
V_{11}	BARI Begun-9 (Dohazari)	BARI
V_{12}	BARI Begun-10 (Bholanath)	BARI
V_{13}	BARI Hybrid Begun-4	BARI

*BARI= Bangladesh Agricultural Research Institute

3.2.2.7. Collection and sowing of brinjal seeds

The seeds of 13 sample brinjal varieties were collected from BARI, Joydebpur, Gazipur. Before sowing, seeds were pre-soaked for 24 hrs to ensure germination. The seeds of all brinjal varieties were sown separately in the seedbed on 16th October, 2016. Intensive care and all necessary intercultural operations including irrigation, weeding, thinning etc. were done in proper time to obtain healthy seedlings.

Plate 14: Seed bed preparation

Plate 15: Preparation of soil for polybag

Plate 16: Polybag preparation

Plate 17: Raising of seedling in the polybag

Plate 18: Growing seedling in the main field after transplanting

Plate 19: Signboard of the experimental field

3.2.2.8. Seedling transplanting

One-month-old seedlings of different brinjal varieties were transplanted in the well-prepared pits of unit plots assigned for each variety according to the design and layout of the experiment.

The necessary intercultural operations including irrigation, weeding, top dressing of nitrogen fertilizer, tagging, etc. were done in proper time. Healthy and uniform sized seedling of 30-days-old were transplanted in the experimental plots in the afternoon, maintaining a spacing of 50 cm between the rows and 50 cm between the plants. The seedlings were watered after transplanting and continued for several days for their establishment in the field. Excess seedlings were also planted around the border of the experimental plots for future gap filling.

3.2.2.9. Intercultural operations

Gap filling

At the time of transplanting few seedlings were transplanted in the border of the experimental plots for gap filling. Very few numbers of seedlings were damaged after transplanting and such seedling were replaced by healthy seedlings of same cultivar. The seedlings were transplanted with a mass of soil roots to minimize the transplanting shock.

Irrigation

After transplanting light irrigation was given to each plot. Supplementary irrigation was applied at an interval of 2-3 days. Stagnant water was effectively drained out at the time of over irrigation. The urea was top dressed in three splits as mentioned earlier.

Weeding

Weeding was done as and when necessary to break the soil crust and to keep the plots free from weeds. First weeding was done after 20 days of planting and the rest were carried out at an interval of 15 days to keep the plot free from weeds.

Earthing up

Earthing up was done in each plot to provide more soil at the base of each plant. It was done at 40 and 60 days after transplanting.

3.2.2.10. Data collection

3.2.2.10.1. Infestation level

Infestation caused by brinjal shoot and fruit borer was monitored during both vegetative and reproductive stages of the brinjal plants. Five plants per plot were selected randomly and tagged for data collection. Infested shoots and fruits were counted and recorded at 7 days intervals after observing the bores and larval excreta in both vegetative and reproductive stage of the plants. The data were recorded on the following parameters throughout the growing period of the crops:

a) **Total number of shoots per plant:** The total number of shoots per 5 tagged plants per plot was recorded for each of 13 brinjal varieties at 7 days interval and the average number of shoots per plant was calculated.

b) **Number of infested shoots per plant:** Number of infested shoots per 5 tagged plants per plot was recorded for each of 13 brinjal varieties at 7 days interval and the average number of infested shoots per plant was calculated.

c) **Percent shoot infestation:** The percent shoot infestation caused by BSFB was calculated using the above-mentioned total number of shoots per plant and number of infested shoots per plant.

d) **Total number of fruits per plant:** The total number of fruits per 5 tagged plants per plot was recorded for each of 13 brinjal varieties at 7 days interval and the average number of fruits per plant was calculated.

e) **Number of infested fruits per plant:** Number of infested fruits per 5 tagged plants per plot was recorded for each of 13 brinjal varieties at 7 days interval and the average number of infested fruits per plant was calculated.

f) **Percent fruit infestation by number:** The percent fruit infestation by number caused by BSFB was calculated using the above-mentioned total number of fruits per plant and number of infested fruits per plant.

g) **Total weight of fruits per plant:** Weight of total fruits per 5 tagged plants per plot was recorded for each of 13 brinjal varieties at 7 days interval and the average weight of total fruits per plant was calculated.

h) **Weight of infested fruits per plant:** Weight of infested fruits per 5 tagged plants per plot was recorded for each of 13 brinjal varieties at 7 days interval and the average weight of infested fruits per plant was calculated.

i) **Percent fruit infestation by weight:** The percent fruit infestation by weight basis caused by BSFB was calculated using the above-mentioned total weight of fruits per plant and weight of infested fruits per plant.

j) **Infestation intensity:** Number of bore per 10 randomly selected infested fruits per plot for each of 13 brinjal varieties was recorded to determine the infestation intensity of fruits.

3.2.2.10.2. Yield attributes and yield

a) **Number of branches:** Total number of branches per 5 tagged plants per plot was recorded for each of 13 brinjal varieties at 7 days interval and the average number of branches per plant was calculated.

b) **Number of leaves:** Total number of leaves per 5 tagged plants per plot was recorded for each of 13 brinjal varieties at 7 days interval and the average number of leaves per plant was calculated.

c) **Number of fruits:** Total number of fruits per 5 tagged plants per plot was recorded for each of 13 brinjal varieties at 7 days interval and the average number of fruits per plant was calculated.

d) **Single fruit weight:** Total weight of fruits per 5 tagged plants per plot was recorded for each of 13 brinjal varieties at 7 days interval and the average weight of fruits per plant was calculated.

e) **Length of fruit:** Total length of fruits per 5 tagged plants per plot was recorded for each of 13 brinjal varieties at 7 days interval and the average length of fruits per plant was calculated.

f) **Girth of fruit:** Total girth of fruits per 5 tagged plants per plot was recorded for each of 13 brinjal varieties at 7 days interval and the average girth of fruits per plant was calculated.

g) **Weight of fruit:** Total weight of fruits per 5 tagged plants per plot was recorded for each of 13 brinjal varieties at 7 days interval and the average weight of fruits per plant was calculated.

h) **Fruits yield per hectare:** Fruits per plot were converted into hectare and the weight of fruits per hectare was calculated and expressed in ton.

3.2.2.11. Data calculation

The percent infestation of shoot and fruit on the basis of recorded data were calculated with the following procedure:

a) Shoot infestation: The percent shoot infestation was calculated using the number of infested shoots and total number of shoots recorded in the study as follows:

$$\%\text{ Shoot infestation} = \frac{\text{Number of infested shoots}}{\text{Total number of shoots}} \times 100$$

b) Fruit infestation: The percent fruit infestation by number and weight was calculated using the number and weight of infested shoots and total number and weight of shoots, respectively recorded in the study as follows:

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

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

% Reduction of infested fruit by length =

$$\frac{\text{Mean length of healthy fruits} - \text{Mean length of infested fruits}}{\text{Mean length of healthy fruits}} \times 100$$

% Reduction of infested fruit by girth =

$$\frac{\text{Mean girth of healthy fruits} - \text{Mean girth of infested fruits}}{\text{Mean girth of healthy fruits}} \times 100$$

3.2.2.12. Determination of tolerance/resistance factor

a) Leaf thorn density: Number of leaf thorns on fully opened top 3 leaves per 5 selected plants per plot was counted through visual inspection and recorded for each of 13 brinjal varieties at 7 days interval.

b) Stem thorns density: Number of thorns on top 10 cm of stem per 5 selected plants per lot was counted through visual inspection and recorded for each of 13 brinjal varieties at 7 days interval.

c) Leaf trichome hair density: Number of trichome hairs per 1 cm^2 of fully opened top 3 leaves per 5 selected plants per plot was observed through stereo microscope, counted and recorded for each of 13 brinjal varieties at 7 days interval.

d) Leaf moisture content: The moisture content of fully opened top 3 leaves per 5 selected plants per plot was measured using oven. For this purpose, variety-wise fresh leaves collected from the field were weighed and recorded for each of 13 brinjal varieties. Then the leaves were dried in the oven at 70°C temperature for 24 hours and the weight of dried leaves was measured for each variety and replication. Finally, the amount of moisture removed from the leaves and percent leaf moisture content was calculated using the following formula:

$$\%\ \text{Leaf moisture content} = \frac{\text{Weight of fresh leaves} - \text{Weight of oven dried leaves}}{\text{Weight of fresh leaves}} \times 100$$

Plate 20: BARI Bt Begun 1

Plate 21: BARI Bt Begun 2

Plate 22: BARI Bt Begun 3

Plate 23: BARI Bt Begun 4

Plate 24: BARI Begun-1

Plate 25: BARI Begun-4

Plate 26: BARI Begun 5

Plate 27: BARI Begun 6

Plate 28: BARI Begun 7

Plate 29: BARI Begun 8

Plate 30: BARI Begun 9

Plate 31: BARI Begun 10

Plate 32: BARI Hybrid Begun-4

Plate 33: Infested Shoot

Plate 34: Larvae in the infested shoot

Plate 35: Showing exit hole of matured larvae

Plate 36: Larvae in the infested fruit

3.2.2.13. Data analysis

The data recorded from the field on different parameters were analyzed using the MSTAT-C computer package to determine the level of significance among 13 brinjal varieties. The means for different brinjal varieties were separated through test of significance using Duncan's Multiple Range Test (DMRT). The possible correlations were also done for different paired variables. The necessary graphs and other calculations were also made using MS Excel Office program/software.

Experiment-3: Efficiency of different pheromone traps and their setting positions for capturing adult moth of *Leucinodes orbonalis*

Objectives

- To find out the effectiveness of different types of pheromone traps for capturing adult moths of BSFB;
- To identify the effectiveness of different setting methods of traps for capturing adult moths of BSFB

The experiment was conducted to findout the efficiency of pheromone traps and trapping methods for capturing adult moths of brinjal shoot and fruit borer. The materials and methods include a short description of the location of experimental site, soil and climate conditions of the experimental area, materials used for the experiment, design of experiment, data collection and data analysis procedure and these are presented below:

3.2.3.1. Experimental period

This experiment on findout the effectiveness of different types of traps and their setting methods for capturing adult BSFB moth was conducted during the period from October 2017 to May 2018.

3.2.3.2. Description of experimental site

The experiment was conducted at the experimental farm of Sher-e-Bangla Agricultural University, Dhaka. It was located in 90.2^{o}N and 23.5^{o}E latitude. The altitude of the location was 8 m above from the sea level as per the Bangladesh Metrological Department, Agargaon, Dhaka-1207 (Appendix III).

3.2.3.3. 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 V. The experiment was carried out during rabi season of 2017-18. Air temperature during the cropping period ranged from 13.32 to 34.12°C. The relative humidity varied from 62.55 to 96.70% and monthly rainfall varied from 0.64 to 12.12 mm from the beginning of the experiment to harvest. The monthly maximum and minimum temperature, humidity and rainfall of the site during the experimental period are given in Appendix V.

3.2.3.4. Soil characteristics

The soil of the experimental field belongs to the Tejgaon series of AEZ No. 28, Madhupur Tract and has been classified as Shallow Red Brown Terrace Soils in Bangladesh soil classification system. 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, ground and passed through 2 mm sieve and analyzed from some important physical and chemical parameters. Some initial physical and chemical characteristics of the soil are presented in Appendix IV.

3.2.3.5. Materials used

Brinjal variety BARI Bagun-1 (Uttara) was used as the test crop for this experiment. The seeds of this brinjal variety were collected from Horticulture Research Centre (HRC), Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur.

3.2.3.6. Treatments of the experiment

This experiment was designed considering two-factor RCBD design, where pheromone trap was considered as Factor A, which level was three such as BARI trap I, BARI trap II and dry trap. On the other hand, setting position of pheromone traps was considered as Factor B, which level was also three such as above upper canopy level, at upper canopy level and lower canopy level. Different levels of Factor A, Factor B and their combinations are presented in the following table (Table 3.3):

Table 3.3.: Arrangement of different types of pheromone traps (Factor A) and their setting position (Factor B)

Factor A		Factor B		Combinations of Factor A and Factor B	Discription
Level	**Types**	**Level**	**Setting position**		
T_1	BARI trap I	L_1	Upper canopy level	T_1 L_1	BARI Trap I set at the upper canopy level
		L_2	Canopy level	T_1 L_2	BARI Trap I set at the canopy level
		L_3	Lower canopy level	T_1 L_3	BARI Trap I set at the lower canopy level
T_2	BARI trap II	L_1	Upper canopy level	T_2 L_1	BARI Trap II set at the upper canopy level
		L_2	Canopy level	T_2 L_2	BARI Trap II set at the canopy level
		L_3	Lower canopy level	T_2 L_3	BARI Trap II set at the lower canopy level
T_3	Dry Pheromone trap	L_1	Upper canopy level	T_3 L_1	Dry pheromone trap (funnel trap) set at the upper canopy level
		L_2	Canopy level	T_3 L_2	Dry pheromone trap (funnel trap) set at the canopy level
		L_3	Lower canopy level	T_3 L_3	Dry pheromone trap (funnel trap) at the lower canopy level

3.2.3.7. 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 field was 331.5 m^2 with the length of 25.5 m and 13.0 m width. The total area was divided into three equal blocks. Each block was divided into 9 plots where 9 treatments combination were assigned at random. There were 27-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 5.0 m, respectively. The layout of the experiment is shown in Appendix VI.

3.2.3.8. Seedling raising

Brinjal seedlings were raised in seed beds of 3.0 m × 1.0 m size plot. The soil was well prepared and converted into loosely friable and dried for seedbed. All weeds and stubbles were removed and well rotten cowdung was mixed with the soil. In each seedbed, seeds were sown on 4^{th} November, 2018. After sowing, seeds were covered with light soil. Sevin 85 WP was applied in the seedbed @ 4 kg ha^{-1}, as precautionary measures against ants and worms. The emergence of 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.

3.2.3.9. Land preparation

The field selected for conducting the experiment was opened in the 2nd week of November 2018 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 for transplanting brinjal seedlings. The experimental plot was partitioned into unit blocks and blocks into unit plots in accordance with the design mentioned earlier.

3.2.3.10. Application of manure and fertilizers

The sources of N, P, K and S as urea, TSP, MoP and Gypsum were applied, respectively. The entire amounts of TSP and Gypsum 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 quantity below. MoP was applied in basal at 15 days after transplanting and during fruiting stage with the amount was as per the mentioned amount 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 is shown as tabular form recommended by BARI (2011).

Manure 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	-	-	-
MoP	250 kg	125 kg	50 kg	75 kg	-
Gypsum	100 kg	100 kg	-	-	-

3.2.3.11. Transplanting of seedlings

Healthy and uniform size of brinjal seedlings were uprooted separately from the seed bed and transplanted in the experimental plots in the afternoon of 24th November, 2018 with maintaining 60 cm distance from row to row and 60 cm from plant-to-plant distance. This allowed an accommodation of 15 plants in each plot. The seedbed was watered before uprooting the seedlings from the seedbed so as to minimize damage to the roots.

3.2.3.12. Intercultural operations

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

3.2.3.13. 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.

3.2.3.14. Stacking

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

3.2.3.15. Weeding

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

3.2.3.16. Top dressing

Urea and MoP 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.

3.2.3.17. Pheromone trap optimization

Three different types of traps, *viz*. BARI trap I, BARI trap II, and Dry trap were evaluated in this experiment. All types of traps at above upper-canopy level, canopy level and lower canopy level is presented in Plate 10. (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 lure was tied inside the trap with thin wire. BSFB adult moth entered into the trap and fell into the water and died. Water inside the trap were replenished often to make sure the trap is not dry. Pheromone dispensers were replaced at every 30 days interval and it was continued throughout the cropping season.

Plate 37. BARI trap 1

Plate 38. BARI trap II

Plate 39. Dry trap

Plate 40. Lure

Plate 41: Adult Moth captured by Pheromone Trap

3.2.3.18. Crop sampling and data collection

Five plants from each treatment were randomly selected and tagged inside the central row of each plot with the help of sampling card.

3.2.3.19. Monitoring and data collection

The brinjal plants under different treatments 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 by weight (%)
- Plant height at harvest (cm)
- Individual fruits weight (g)
- Fruit yield per hectare (ton)

3.2.3.20. 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:

$$\% \text{ Infestation of shoot} = \frac{\text{Number of infested shoots}}{\text{Total number of shoots}} \times 100$$

3.2.3.21. 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:

$$\% \text{ Infestation of fruit by number} = \frac{\text{Number of infested fruits}}{\text{Total number of fruits}} \times 100$$

3.2.3.22. Determination of fruit infestation in weight

All the healthy and infested fruits were weighed 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:

$$\% \text{ Infestation of fruit by weight} = \frac{\text{Weight of infested fruit}}{\text{Total number of fruits}} \times 100$$

3.2.3.23. 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.

3.2.3.24. Procedure of data collection

a) 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.

b) 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).

c) Fruits yield per hectare

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

3.2.3.25. 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).

Experiment-4: Effectiveness of botanicals and other non-chemical approaches against BSFB in comparison with chemical insecticides

Objectives

- To evaluate the efficiency of botanicals, pheromone traps and other non-chemical methods against BSFB in comparison with chemical insecticides;
- To find out the eco-friendly management practices of BSFB in comparison with traditional practices.

The experiment on the effectiveness of botanicals and other non-chemical approaches against BSFB in comparison with chemical insecticides was carried out at the experiment field of the Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh during October, 2018 to March, 2019. The materials and methods adopted in this study are discussed in the following sub headings:

3.2.4.1. Experimental site

Detailed about the experimental site was given in section 3.2.3.2.

3.2.4.2. Climatic conditions

Detailed about the climatic condition of the experimental site was given in section 3.2.3.3.

3.2.4.3. Characteristics of Soil

Detailed about the soil characteristics of the experimental site was given in section 3.2.3.4.

3.2.4.4. Design and layout

The study was conducted considering eight treatments including a control for controlling sucking pest at seedling to harvesting stage. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications in the field of the Entomology Department. The whole field was divided three blocks of equal size and each block was sub divided into nine plots. The unit plot size was 3m×2m accommodating twelve pits per plot. The distance between row to row was 100 cm and that of the plants to plants was 70 cm (Appendix VI).

3.2.4.5. Land preparation

The soil of the experimental field was well prepared thoroughly followed by plowing and cross plowing, leveling and laddering to have a good tilth. All weeds and debris of previous crops were removed and land was finally prepared with the addition of basal dose of well decomposed cowdung. The plots were raised by 10 cm from the soil surface keeping the drain around the plots.

3.2.4.6. Manuring and fertilization

The following doses of manure and fertilizers were applied as per recommendation doses of brinjal.

Manure/ Fertilizers	Dose per ha
Cow-dung	10 tons
Urea	360 Kg
Triple Super Phosphate (TSP)	150 Kg
Muriate of Potash	250 Kg

The full dose cow-dung and TSP were applied as basal dose during final land preparation. One-third of the MP and urea were applied in the pits one week before transplanting and rest of the MP and urea were applied as the top dressing at 21, 35 and 50 days after transplanting.

3.2.4.7. Raising of seedling and transplanting

Brinjal seed (Vatiety: BARI brinjal-1, Uttara) were collected from BARI, Gazipur, Dhaka. A small seedbed measuring 5m×1m was prepared and seeds were sown in the nursery bed at SAU Entomology field on 17 October, 2018. Standard seedling raising practice was followed. The plots were lightly irrigated regularly for ensuring proper development of the seedlings. The seedbed was mulched for ensuring proper seed germination, proper growth and development of the seedlings. Thirty-days-old healthy seedlings were transplanted in polybag for hardening. After thirty days that seedlings were transplanted on 17 December, 2018 in the experimental field.

3.2.4.8. Intercultural operations

a) Gap filling

At the time of transplanting a few seedlings were transplanted in the border of the experimental plots for gap filling. Very few numbers of seedlings were damaged after transplanting and such seedling were replaced by healthy seedlings from the same aged seedling planted earlier on the border of the experimental plot. The seedlings were transplanted with a mass of soil roots to minimize the transplanting shock.

b) Irrigation

After transplanting light irrigation was given to each plot. Supplementary irrigation was applied at an interval of 2-3 days. Stagnant water was effectively drained out at the time of over irrigation. The urea was top dressed in three splits as mentioned earlier.

c) Weeding

Weeding was done as and when necessary to break the soil crust and to keep the plots free from weeds. First weeding was done after 20 days of planting and the rest were carried out at an interval of 15 days to keep the plot free from weeds.

d) Earthing up

Earthing up was done in each plot to provide more soil at the base of each plant. It was done 40 and 60 days after transplanting.

3.2.4.9. Treatment for control measures

The experiment was evaluated to find out effectiveness of botanicals and other non-chemical approaches against BSFB in comparison with chemical insecticides to compare with each other in considering the less hazardous but effective control measures against BSFB of brinjal. The treatments as well as their doses to be used in the study are given below:-

T_1= Spraying of Neem oil (azadirachtin) @ 3.0 ml/L of water at 7 days interval

T_2= Spraying of Neem seed kernel extract (azadirachtin) @ 3.0 ml/L of water at 7 days interval

T_3= Mechanical control (Collection and destruction of infested shoots and fruits)

T_4= Pheromone trap located at the canopy level @ 1 lure at 30 days interval

T_5= Spraying of Tracer 45SC (spinosad) @ 0.4 ml/L of water at 7 days interval

T_6= Spraying of Marshal 20EC (carbosulfan) @ 3 ml/L of water at 7 days interval

T_7= Spraying of Suntap 50SP (cartap) @ 1.5 g/L of water at 7 days interval

T_8= Untreated control.

3.2.4.10. Treatment preparation

a) Neem oil

The Neem oil was collected from Chawkbazar, Dhaka and the trix liquid detergent was collected from the local market of Agargoan bazaar, Dhaka. All sprays were made according to the methods described earlier. For each neem oil application, 15 ml neem oil (@ 3.0 ml/L of water i.e. 0.3% per 5 liter of water was used. The mixture within the spray machine was shaked well and sprayed on the upper and lower surface of the plants of the treatment until the drop run off from the plant. Three liters spray material was required to spray in three plots of each replication.

b) Neem seed kernel

The mature and dried neem seeds were collected from the neem tree found in the Horticulture Garden of SAU. Then seeds were roasted by electric oven. Then the seed kernel was separated and taken into the electric blender for blending. 250 gm of neem seed kernel powder was taken into a beaker and 250 ml water was added into the beaker. Then the beaker was shaken by electric stirrer for mixing up thoroughly the mixture. The aqueous mixture then filtered using Whatmen paper filter and preserved the aqueous extracts of neem seed kernel in the refrigerator at 4^{o}C for spraying in the field.

c) Management with pheromone trap

Sex pheromone trap designed by BARI with cue-lure and soapy water, were used to conduct this experiment. The traps were hung up under bamboo scaffold, 60 cm above the ground (canopy level). The soap water was replaced by new soap water at an interval of 4 days. After four days interval the number of insects trapped was recorded. In case of trapping, number of trapped moths was counted. Total fruit and infested fruits were recorded and percentage of infested fruit was calculated.

d) Spinosad

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

3.2.4.11. Treatment application

T_1: Neem oil @ 3.0 ml/L of water was sprayed at 7 days interval. Under this treatment, neem oil was applied @ 15 ml /5L of water mixed with trix liquid detergent @ 10 ml (1%) to make the oil easily soluble in water. After proper shaking, the prepared spray was applied with a high-volume Knapsack sprayer at 7 days intervals commencing from 20 DAT.

T_2: Neem seed kernel extract @ 3.0 ml/L of water was sprayed at 7 days. Under this treatment, neem seed kernel extract was applied @ 15 ml /5L of water. After proper shaking, the prepared spray was applied with a high-volume Knapsack sprayer at 7 days intervals commencing from 20 DAT.

T_3: Collection and destruction of infested shoot and fruits caused by BSFB. Data was collected from the field at 7 days intervals commencing from 20 DAT.

T_4: Pheromone trap was used one for a plot for one month. The soapy water was replaced by new soap water at an interval of five days commencing from 20 DAT.

T_5: Spinosad @ 0.08 ml/L of water was sprayed at 7 days interval. For this treatment 1.0 ml of insecticides per 5 liter of water was mixed and sprayed at 7 days intervals commencing from 20 DAT.

T_6: Marshal 20 EC @ 0.1 ml/L of water was sprayed at 7 days interval. For this treatment 1.0 ml of insecticides per 5 liter of water was mixed and sprayed at 7 days intervals commencing from 20 DAT.

T_7: Suntap 50 SP @ 1.0 ml/L of water was sprayed at 7 days interval. For this treatment 5.0 ml of insecticides per 5 liter of water was mixed and sprayed at 7 days intervals commencing from 20 DAT.

T_8: Untreated control. There was no any control measure was applied in brinjal field.

3.2.4.12. Data collection

The data collection was started just before application of treatment and after spray 7 days interval on the following parameters:

- **Total number of fruits:** For the estimation of total number of fruits per plant, fruits were randomly selected and counted from each plant, at each time of data collection.
- **Number of infested fruits:** For the estimation of number of infested fruits per plant, fruits were randomly selected and counted from each plant, at each time of data collection.
- **Total number of branches:** For the estimation of total number of branches per plant, branches were selected and counted from each plant, at each time of data collection.
- **Number of infested branches:** For the estimation of number of infested branches per plant, branches were selected and counted from each plant, at each time of data collection.
- **Total weight of fruits:** For the estimation of total weight of fruits per plant, fruits were randomly selected and weight was recorded, from each plant, at each time of data collection.
- **Weight of infested fruits:** For the estimation of weight of infested fruits per plant, fruits were randomly selected and weight recorded, from each plant, at each time of data collection.
- **Weight of edible portion of the infested fruits:** For the estimation of weight of edible portion of the infested fruits per fruit, the infested fruits are collected and weight of edible portion recorded.
- **Length of healthy and infested fruits:** For the estimation of length of 10 randomly selected healthy and infested fruits per plot, fruits were randomly selected and length recorded, from each plot, at each time of data collection.

- **Girth of healthy and infested fruits:** For the estimation of girth of 10 randomly selected healthy and infested fruits per plot, fruits were randomly selected and girth recorded, from each plot, at each time of data collection.
- **Yield of fruits:** For the estimation of yield per plant and plot total fruits were collected and weight recorded, from each plant and plot, at each time of data collection.
- **Number of bore:** For the estimation of total number of bores per fruit, fruits were selected and counted from each fruit, at each time of data collection.
- **Number of beneficial arthropods:** For the estimation of total number of lady bird beetle, ant, Trichogamma, honey bee and spider per plot, counted from each plot, at each time of data collection.

3.2.4.13. Calculation of the infestation level

a) The infested leaves were calculated by the following procedure:

Number of infested leaves was counted from total fruits per plants and percent fruit infestation by BSFB of brinjal were calculated as follows:

$$\text{\% Infestation of fruit by number} = \frac{Number\ of\ infested\ fruits}{Total\ number\ of fruits} \times 100$$

b) The infested branches were calculated by the following procedure:

Number of infested branches was counted from per plant and percent branches infestation by BSFB of brinjal were calculated as follows:

$$\text{\% Infestation of branches} = \frac{Number\ of\ infested\ branches}{Total\ number\ of\ branches} \times 100$$

c) Percent edible fruit weight calculated by the following procedure:

Percent edible fruit weight of infested fruit weight infestated by BSFB of brinjal were calculated as follows:

$$\text{\% Edible fruit weight} = \frac{Edible\ fruit\ weight}{Total\ infested\ fruit\ weight} \times 100$$

d) Percent non-edible fruit weight calculated by the following procedure:

Percent non-edible fruit weight of total infested fruit weight infestated by BSFB of brinjal were calculated as follows:

$$\% \text{ Non-edible fruit weight} = \frac{Non\text{−}edible\ fruit\ weight}{Total\ infested\ fruit\ weight} \times 100$$

3.2.4.14. Statistical analysis

Data were analyzed by using MSTAT-C software for analysis of variance after square root transformation. ANOVA was made by F variance test and the pair comparisons were performed by Duncan Multiple Range Test (DMRT).

Experiment-5: Development of IPM packages against BSFB for safe and hazard free brinjal production

Objectives

- To integrate in the best possible combinations of the tools identified from the previous experiment as effective to develop effective IPM package against BSFB on eggplant
- To find out the safe and hazards free integrated package for combating BSFB

The experiment on the effectiveness of botanicals and other non-chemical approaches against BSFB in comparison with chemical insecticides was carried out at the experiment field of the Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh during October, 2019 to March, 2020. The materials and methods adopted in this study are discussed in the following sub headings:

3.2.5.1. Experimental site

Detailed about the experimental site was given in section 3.2.3.2.

3.2.5.2. Climatic conditions

Detailed about the climatic condition of the experimental site was given in section 3.2.3.3.

3.2.5.3. Characteristics of Soil

Detailed about the soil characteristics of the experimental site was given in section 3.2.3.4.

3.2.5.4. Design and layout

Detailed about the design and layout of the experiment (Appenix VI) was given in section 3.2.4.4.

3.2.5.5. Land preparation

Detailed about the land preparation for this study was given in section 3.2.4.5.

3.2.5.6. Manuring and fertilization

Detailed about the manuring and fertilizers application for this study was given in section 3.2.4.6.

3.2.5.7. Raising of seedling and transplanting

Brinjal seed (Vatiety: BARI brinjal-1, Uttara) were collected from BARI, Gazipur, Dhaka. A small seedbed measuring 5m×1m was prepared and seeds were sown in the nursery bed at SAU Entomology field on 15 October, 2019. Standard seedling raising practice was followed. The plots were lightly irrigated regularly for ensuring seed proper development of the seedlings. The seedbed was mulched for ensuring proper seed germination, proper growth and development of the seedlings. Thirty-days-old healthy seedlings were transplanted in polybag for hardening. After thirty days that seedlings were transplanted on 16 December, 2019 in the experimental field.

3.2.5.8. Intercultural operations

a) Gap filling

Detailed about the gap filling was given in section 3.2.4.8.(a).

b) Irrigation

Detailed about irrigation was given in section 3.2.4.8.(b).

c) Weeding

Detailed about weeding was given in section 3.2.4.8.(c).

d) Earthing up

Detailed about earthing up was given in section 3.2.4.8.(d).

Plate 42: Experimental field

Plate 43: Setting of pheromone trap in the field

Plate 44: Shoot infestation by BSFB

Plate 45: Fruit infestation by BSFB

Plate 46: BSFB larvae in the infested fruit

Plate 47: Healthy fruit

3.2.5.9. Treatment for control measures

The experiment was conducted to determine the the development of integrated pest management (IPM) approach for combating cucurbit fruit fly of bitter gourd. The IPM based packages were used in the study are given below:-

Package 1: Pheromone Trap located at the canopy level @ 1 lure at 30 days interval + Collection and destruction of BSFB infested shoots and fruits at 7 days interval

Package 2: Pheromone Trap located at the canopy level @ 1 lure at 30 days interval + Use of Bio-Neem plus (azadirachtin) @ 3.0 ml/L of water at 7 days interval

Package 3: Pheromone Trap located at the canopy level @ 1 lure at 30 days interval + Spraying of Neem oil (azadirachtin) @ 3.0 ml/L of water at 7 days interval

Package 4: Pheromone Trap located at the canopy level @ 1 lure at 30 days interval + Spraying of Proclaim 5SG (Emamectin Benzoate) @ 3.0 g/L at 7 days interval

Package 5: Pheromone Trap located at the canopy level @ 1 lure at 30 days interval + Spraying of Marshal 20EC (carbosulfan) @ 3.0 ml/L of water at 7 days interval

Package 6: Pheromone Trap located at the canopy level @ 1 lure at 30 days interval + Spraying of Bio-Neem plus (azadirachtin) @ 3.0 ml/L of water and Marshal 20EC (carbosulfan) @ 3.0 ml/L of water at alternate 7 days interval, respectively

Package 7: Pheromone Trap located at the canopy level @ 1 lure at 30 days interval + Spraying of Neem oil (azadirachtin) @ 3.0 ml/L and Marshal 20EC (carbosulfan) @ 3.0 ml/L of water at alternate 7 days interval, respectively

Package 8: Pheromone Trap located at the canopy level @ 1 lure at 30 days interval + Spraying of Bio-Neem plus (azadirachtin) @ 3.0 ml/L of water and Proclaim 5SG (Emamectin Benzoate) @ 3.0 g/L at alternate 7 days interval, respectively

Package 9: Pheromone Trap located at the canopy level + Spraying of Neem oil (azadirachtin) @ 3.0 ml/L and Proclaim 5SG (Emamectin Benzoate) @ 3.0 g/L at alternate 7 days interval, respectively

Package 10: Untreated control

3.2.5.10. Treatment preparation

a) Neem oil

Detailed about the preparation of neem oil was given in section 3.2.4.10.(a).

b) Neem seed kernel extract

Detailed about the preparation of neem seed kernel extract was given in section 3.2.4.10.(b).

c) Management with pheromone trap

Detailed about the pheromone trap setting was given in section 3.2.4.10.(c).

d) Bioneem plus

The bioneem plus was collected from Chawkbazar, Dhaka and the trix liquid detergent was collected from the local market of Agargoan Bazaar, Dhaka. All sprays were made according to the methods described earlier. For each Bioneem Plus application, 15 ml Bioneem Plus (@ 3.0 ml/L of water i.e. 0.3% per 5 liter of water was used. The mixture within the spray machine was shaked well and sprayed on the upper and lower surface of the plants of the treatment until the drop run off from the plant. Three liters spray material was required to spray in three plots of each replication.

e) Proclaim

Proclaim was collected from Chawkbazar, Dhaka and the trix liquid detergent was collected from the local market of Agargoan Bazaar, Dhaka. All sprays were made according to the methods described earlier. For each proclaim application, 15 g proclaim (@ 3.0 g/L of water i.e. 0.3% per 5 liter of water was used. The mixture within the spray machine was shaked well and sprayed on the upper and lower surface of the plants of the treatment until the drop run off from the plant. Three liters spray material was required to spray in three plots of each replication.

3.2.5.11. IPM Packages application

Package 1: Pheromone trap was used one for a plot for one month. The soapy water was replaced by new soapy water at an interval of five days commencing from 20 DAT. Colloection and destruction of BSFB infested shoots and fruits at 7 days interval.

Package 2: Pheromone trap was used one for a plot for one month. The soapy water was replaced by new soapy water at an interval of five days commencing from 20 DAT. Bio-neem plus was applied @ 3.0 ml/L of water mixed with trix. After proper shaking, the prepared spray was applied with a high-volume Knapsack sprayer at 7 days intervals commencing from 20 DAT.

Package 3: Pheromone trap was used one for a plot for one month. The soapy water was replaced by new soapy water at an interval of five days commencing from 20 DAT. Neem oil @ 3.0 ml/L of water was sprayed at 7 days interval. Under this treatment, neem oil was applied @ 9 ml /3L of water mixed with trix liquid detergent @ 10 ml (1%) to make the oil easy soluble in water. After proper shaking, the prepared spray was applied with a high-volume Knapsack sprayer at 7 days intervals commencing from 20 DAT.

Package 4: Pheromone trap was used one for a plot for one month. The soapy water was replaced by new soapy water at an interval of five days commencing from 20 DAT. Proclaim 5 SG @ 3.0 g/L of water was sprayed at 7 days interval. After proper shaking, the prepared spray was applied with a high-volume Knapsack sprayer at 7 days intervals commencing from 20 DAT.

Package 5: Pheromone trap was used one for a plot for one month. The soapy water was replaced by new soapy water at an interval of five days commencing from 20 DAT. Marshal 20 EC @ 3.0 ml/L of water was sprayed at 7 days interval. After proper shaking, the prepared spray was applied with a high-volume Knapsack sprayer at 7 days intervals commencing from 20 DAT.

Package 6: Pheromone trap was used one for a plot. The soapy water was replaced by new soapy water at an interval of five days commencing from 20 DAT. Bio-Neem plus @ 3.0 ml/L of water mixed with trix liquid detergent @ 10 ml (1%) to make the oil easy soluble in water was sprayed at 7 days interval. Under this treatment, Marshal 20 EC @ 3.0 ml /L of water was sprayed at 7 days interval. After proper shaking, the prepared spray was applied with a high-volume Knapsack sprayer at 7 days intervals commencing from 20 DAT.

Package 7: Pheromone trap used one for a plot. The soapy water was replaced by new soapy water at an interval of five days commencing from 20 DAT. Neem oil @ 3.0 ml/L of water was sprayed at 7 days interval. Under this treatment, Marshal 20 EC @ 3.0 ml /L of water was sprayed at 7 days interval. After proper shaking, the prepared spray was applied with a high-volume Knapsack sprayer at 7 days intervals commencing from 20 DAT.

Package 8: Pheromone trap used one for a plot. The soapy water was replaced by new soapy water at an interval of five days commencing from 20 DAT. Under this treatment, Proclaim 5 SG was applied @ 3.0 gm/L of water. Bio-Neem plus @ 3.0 ml/L of water was sprayed at 7 days interval. After proper shaking, the prepared spray was applied with a high-volume Knapsack sprayer at 7 days intervals commencing from 20 DAT.

Package 9: Pheromone trap used one for a plot. The soapy water was replaced by new soapy water at an interval of five days commencing from 20 DAT. Under this treatment, neem oil was applied @ 3.0 ml/L of water mixed with trix liquid detergent @ 10 ml (1%) to make the oil easy soluble in water. Under this treatment, Proclaim 5 SG was applied @ 3.0 g/L of water. Among cultural practices include field sanitation, irrigation, collection and destruction of infested and fallen fruits from the field were done at the seven days intervals commencing from 20 DAT.

Package 10: Untreated control. There was no any control measure was applied in bitter gourd field.

3.2.5.12. Data collection

The data collection was started just before application of treatment and after spray 7 days interval on the following parameters:

- **Total number of fruits:** For the estimation of total number of fruits per plant, fruits were randomly selected and counted from each plant, at each time of data collection.
- **Number of infested fruits:** For the estimation of number of infested fruits per plant, fruits were randomly selected and counted from each plant, at each time of data collection.
- **Total number of branches:** For the estimation of total number of branches per plant, branches were selected and counted from each plant, at each time of data collection.
- **Number of infested branches:** For the estimation of number of infested branches per plant, branches were selected and counted from each plant, at each time of data collection.
- **Total weight of fruits:** For the estimation of total weight of fruits per plant, fruits were randomly selected and weight was recorded, from each plant, at each time of data collection.
- **Weight of infested fruits:** For the estimation of weight of infested fruits per plant, fruits were randomly selected and weight recorded, from each plant, at each time of data collection.
- **Weight of edible portion of the infested fruits:** For the estimation of weight of edible portion of the infested fruits per fruit, the infested fruits are collected and weight of edible portion recorded.
- **Length of healthy and infested fruits:** For the estimation of length of 10 randomly selected healthy and infested fruits per plot, fruits were randomly selected and length recorded, from each plot, at each time of data collection.
- **Girth of healthy and infested fruits:** For the estimation of girth of 10 randomly selected healthy and infested fruits per plot, fruits were randomly selected and girth recorded, from each plot, at each time of data collection.

- **Yield of fruits:** For the estimation of yield per plant and plot total fruits were collected and weight recorded, from each plant and plot, at each time of data collection.

- **Number of bore:** For the estimation of total number of bores per fruit, fruits were selected and counted from each fruit, at each time of data collection.

- **Number of beneficial arthropods:** For the estimation of total number of lady bird beetle, ant, Trichogamma, honey bee and spider per plot, counted from each plot, at each time of data collection.

3.2.5.13. Calculation of the infestation level

a) The infested leaves were calculated by the following procedure:

The detailed about the calculation formula to calculate the infested leaves was given in section 3.2.4.13.(a).

b) The infested branches were calculated by the following procedure:

The detailed about the calculation formula to calculate the infested branches was given in section 3.2.4.13.(b).

c) Percent edible fruit weight calculated by the following procedure:

The detailed about the calculation formula to calculate the percent edible fruit weight was given in section 3.2.4.13.(c).

d) Percent non-edible fruit weight calculated by the following procedure:

The detailed about the calculation formula to calculate the percent non-edible fruit weight was given in Section 3.2.4.13.(d).

3.2.5.14. Statistical analysis

Data were analyzed by using MSTAT-C software for analysis of variance after square root transformation. ANOVA was made by F variance test and the pair comparisons were performed by Duncan Multiple Range Test (DMRT).

CHAPTER IV
RESULTS AND DISCUSSION

Experiment 1: Cross-cutting issues of farmers' practices for the management of brinjal shoot and fruit borer in Bangladesh

This study was conducted during February to June 2016 in 5 brinjal growing districts of Bangladesh aiming to assess the cross-cutting issues of farmers' practices for the management of brinjal shoot and fruit borer (BSFB) in Bangladesh. The survey was conducted with the participation of 310 brinjal farmers in 10 upazila under 5 brinjal growing districts of Bangladesh. The findings of the survey are presented in the following sub-headings:

4.1.1. Demographic profile: Among 310 brinjal farmers participated in the survey, 92.6% farmers were male and remaining were female. Among the farmers who participated in the survey study, out of 310 respondednt brinjal farmers the highest 41.6 percent farmers were under 36 to 45 age group followed by 35.8 percent under 26 to 35 age group, 10.6 percent under 46 to 55 age group, 7.4 percent under 18 to 25 age group and rest 4.5 percent were more than 55 aged farmers. The educational level of maximum 29.67% farmers were up to primary level, 28.67% up to class eight, 16.67% farmers completed SSC, 8.00% completed HSC and 2.33% completed bachelor degree. Conversely, 14.5% farmers had no literacy knowledge.

Table 4.1.1. Demographic profile of farmers participated in the survey

Sl. No.	Response	Number of farmers [N=310]	% Response
(a)	**Sex of the farmers**		
	Male	287	92.6
	Female	23	7.4
	Total	**310**	**100.0**
(b)	**Age of the farmers (years)**		
	18-25	23	7.4
	26-35	111	35.8
	36-45	129	41.6
	46-55	33	10.6
	More than 55	14	4.5
	Total	**310**	**100.0**
(c)	**Education level of the farmers**		
	Illiterate	45	14.5
	Upto primary level	92	29.7
	Upto class eight	89	28.7
	SSC	52	16.8
	HSC	25	8.1
	Bachelor degree	7	2.3
	Total	**310**	**100.0**

4.1.2. Farmers' category: The brinjal farmers participated in the survey were categorized based on the land size. As per survey findings, 53.27% famers were categorized under marginal farmers followed by 38.40% were small farmers and only 8.33% brinjal growers were belonged to medium farmers (Figure 4.1.1). According to BBS (2019), the landless farmers are categorized who don't have any lands, the marginal farmers who have 1-49 decimal agricultural land, small farmers who have 50-249 decimal agricultural land, medium farmers who have 2.5-7.49 acres land, and the large farmers who have more than 7.50 acres of land (BBS 2019).

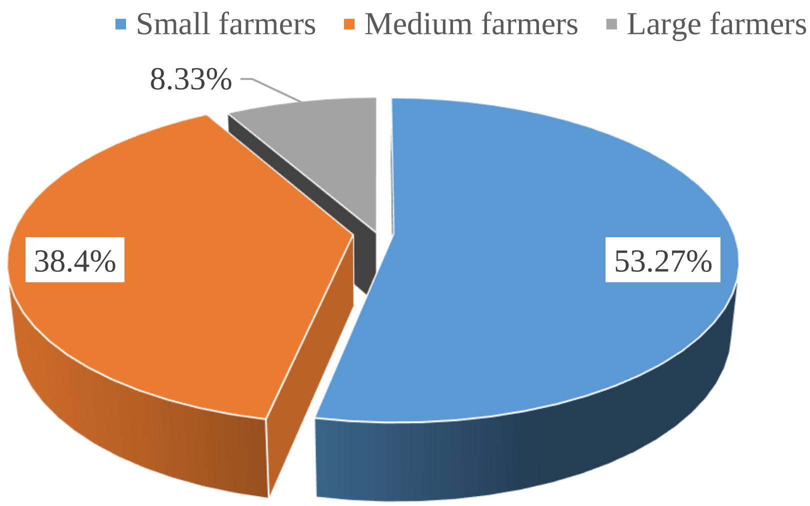


Figure 4.1.1: Category of brinjal farmers based on their land size

4.1.3. Types of crops cultivated: The farmers participated in the survey reported that they cultivated different types of crops, where one farmer usually cultivated more than one crops in their land. As per their response, out of 310, all (100%) farmers cultivated both brinjal and cereal crops in their field, which was closely followed by cultivation of other vegetables (90.00%). This was distantly followed by cultivation of fruits (21.00%), sugarcane (4.00%), fiber crops (6.00%). On the other hand, 9.67% farmers reported that they cultivated other crops mentioning oil seed crops such as mustard, sesame, etc. (Table 4.1.2).

Table-4.1.2. Farmers' response on the type of agricultural production

Types of crops	Number of respondents [N=310]	% Response
Cereal crops	310	100.0
Brinjal	310	100.0
Other vegetables	270	90.0
Fruits	63	21.0
Sugarcane	12	4.0
Fiber crops	18	6.0
Other crops	29	9.7
Multiple response*		

**Multiple response means one respondent provided his/her response on more than one options*

4.1.4. Farmers' experience and land under brinjal cultivation: The brinjal faremrs reported that average years of experience in brinjal cultivation was 9.25 years that was ranged from 1 to 25 years. While the average land size under brinjal cultivation was 26.3 decimal that was ranged from 2.5 to 80 decimal (Table-4.1.3).

Table-4.1.3. Farmers' experience and land under brinjal cultivation

SN	Options	Farmers' response [N=310]
(a)	**Years of experience in brinjal cultivation**	
	Minimum	1
	Maximum	25
	Average	9.25
(b)	**Area of land (decimal) under brinjal cultivation**	
	Minimum	2.5
	Maximum	80
	Average	26.3

4.1.5. Types of brinjal varieties cultivated: The survey findings revealed that, maximum 59.33% farmers cultivated hybrid varieties of brinjal in their field followed by 55.67% cultivated Uttara variety (BARI brinjal-1), 42.0% mentioned Singnath variety, 35 percent famers mentioned Ishwardi (BARI brinjal-6) variety, 31.67 percent farmers cultivated Islampuri variety, 22.33 percent mentioned Khatiya variety, 17 percent farmers mentioned Tarapuri (BARI brinjal-2) variety, 15.33 percent mentioned local variety and others (Table-4.1.4).

Table-4.1.4. Distribution of farmers by cultivation of brinjal varieties

Brinjal varieties	Number of farmers [N=310]	% Response
Uttara (BARI brinjal-1)	167	55.67
Tarapuri (BARI brinjal-2)	51	17.00
Kajla (BARI begun-4)	13	4.33
Nayantara (BARI brinjal-5)	11	3.67
Ishwardi (BARI brinjal-6)	106	35.00
Singnath (BARI brinjal-7)	127	42.33
Islampuri	95	31.67
Khatiya	67	22.33
Laffa	33	11.00
Chega begun (local)	31	10.33
Jhumko	3	1.00
Hybrid variety	178	59.33
Local variety	46	15.33
Bt brinjal	17	5.67
Multiple response*		

**Multiple response means one respondent provided his/her response on more than one options*

4.1.6. Cost of brinjal production and income

To a question of how much cost incurred for brinjal production per decimal area of land, as their answers, average 4,212 Taka was required for brinjal cultivation per decimal area of land that was ranged from 3,500 to 5,000 Taka (Table-4.1.5). While the farmers were asked about a question of how much income earned from per decimal brinjal production, from their response it was revealed that average income was 4,783 Taka that was ranged from 4,000 to 7,500 Taka (Table-4.1.5). The average profit gained from brinjal production as well benefit cost ratio (BCR) was also calculated from the average cost and income earned from brinjal production. The findings revealed that average profit gained from brinjal production was 571 Taka per decimal and 57,100 Taka per acre.

Table-4.1.5. Farmers' response on cost of brinjal production and income earned

SN	Options	Farmers' response [N=310]
(a)	**Cost for brinjal production (Tk per decimal)**	
	Minimum	3,500
	Maximum	5,000
	Average	4,212
(b)	**Income from brinjal cultivation (Tk per decimal)**	
	Minimum	4,000
	Maximum	7,500
	Average	4,783
(c)	**Profit from brinjal cultivation**	
	Average profit (Tk/decimal)	571
	Average profit (Tk/acre)	57,100

4.1.7. Sources of brinjal seeds: To a question of from where the farmers collected/purchased brinjal seeds for cultivation, out of 310 farmers, 92.6 percent farmers purchased brinjal seeds from local market/seed traders that was followed by 41.3 percent farmers collected seeds from seed companies. While 17.1 percent mentioned that they used brinjal seeds from their own source, 14.2 percent mentioned BARI/DAE, 12.3 percent mentioned that they collected seeds from neighboring farmers and 11.6 percent mentioned NGOs (Table-4.1.6).

Table-4.1.6. Distributon of brinjal farmers by source of seeds used for cultivation

Sources of seeds	Number of farmers [N=310]	Response (%)
Farmers' own seeds	53	17.1
Neighboring farmers	38	12.3
BARI/DAE	44	14.2
Seed company	128	41.3
Local market/seed traders	287	92.6
NGOs	36	11.6
Multiple response*		

**Multiple response means one respondent provided his/her response on more than one options*

4.1.8. Farmers' perception about brinjal shoot and fruit borer infestation

(a) Occurrence of brinjal shoot and fruit borer infestation: To a question asked to the farmers, whether the infestation of brinjal shoot and fruit borer occurred in the brinjal field that they cultivated, as their answers, out of 310, all farmers conformed that brinjal shoot and fruit borer infestation occurred in their brinjal field (Figure 4.1.2).

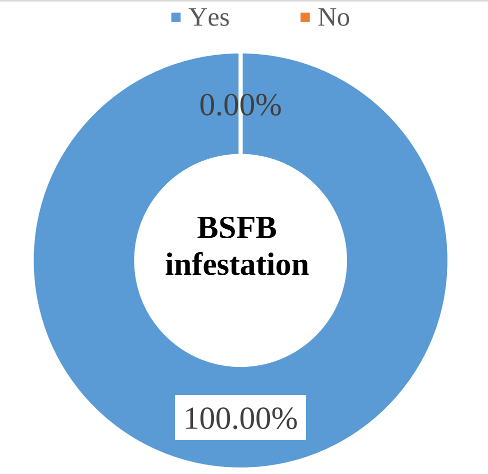


Figure 4.1.2. Farmers' response whether the brinjal shoot and fruit borer infestation occurred

(b) Perception on destructive stages of BSFB: The farmers were asked what stages of brinjal shoot and fruit borer usually caused damage to brinjal, as their answers, out of 310 farmers, 100% of them informed that larval stage of brinjal shoot and fruit borer was the destructive phase for brinjal (Figure 4.1.3).

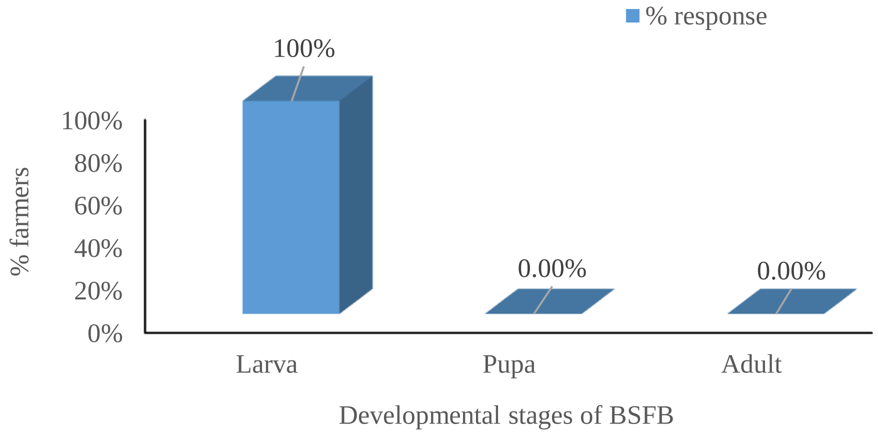


Figure-4.1.3. Farmers' response on destructive stages of BSFB caused damage in brinjal field

(c) Active period of adult BSFB moth: To a question of when the adult moths of brinjal shoot and fruit borer remained active in brinjal field, about 74.8% farmers reported that adult moths of BSFB was found active at morning in their brinjal field, whereas 62.3% farmers mentioned adult moths were found active at night in their brinjal field, while 31% farmers mentioning afternoon and 6.1% farmers mentioned that the adult moths were found active at noon in their brinjal field (Table 4.1.7).

Table-4.1.7. Farmers' perception about active time of adult moths of brinjal shoot and fruit borer in brinjal field

Active time	Number of farmers [N= 310]	% Response
Morning	232	74.8
Afternoon	96	31.0
Noon	19	6.1
Night	193	62.3
Multiple response*		

**Multiple response means one respondent provided his/her response on more than one options*

(d) Seasonal abundance of brinjal shoot and fruit borer: Farmers were asked about a question in which season was the most favorable for brinjal shoot and fruit borer infestation, as their answers, out of 310 farmers, maximum 44.8 percent farmers (139) informed that winter season was the most favorable season for brinjal shoot and fruit borer infestation, while 26.1 percent farmers (81) mentioned rainy season, 18.4 percent farmers (57) mentioning summer season. Some proportion of farmers also mentioned autumn (4.2%), late autumn (3.5%) and spring (2.9%) were the favorable seasons for brinjal shoot and fruit borer infestation in the field (Figure 4.1.4).

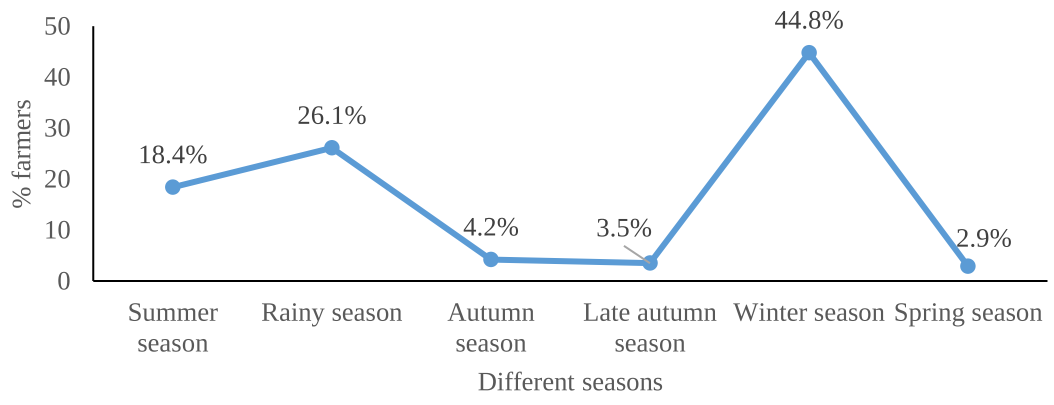


Figure 4.1.4.: Farmers' response on the favorable season for brinjal shoot and fruit borer infestation in the field

(e) Vulnerable parts of brinjal to BSFB: Farmers were asked about a question of which parts of brinjal plant more vulnerable to brinjal shoot and fruit borer infestation, as their answers, out of 310 farmers, about 70 percent reported that the tender shoots of brinjal plant were more vulnerable to brinjal shoot and fruit borer infestation, while 90 percent mentioned that the tender fruits were most vulnerable to the BSFB infestation (Table-4.1.8).

Table-4.1.8. Farmers' response on vulnerable parts of brinjal to BSFB infestation

Vulnerable parts	Number of farmers [N=310]	% Response
Tender shoot	221	71.3
Tender fruit	280	90.3
Fruit calyx	31	10.0
Multiple response*		

**Multiple response means one respondent provided his/her response on more than one options*

(f) Extent of damage caused by brinjal shoot and fruit borer: To a question about what extent of damage occurred in the brinjal field due to BSFB infestation, as their answers, out of 310 farmers, maximum 83 percent of them reported that BSFB damaged about 11 to 25 percent shoots, while 10 percent farmers mentioned less than 10 percent shoot damage, 6 percent farmers mentioned 26 to 50 percent shoot damage, and only 2 percent farmers mentioned about 51 to 75 percent shoot damage.

In case of fruit damage, out of 310 farmers, maximum 54 percent of them reported that BSFB damaged about 26 to 50 percent fruits, while 20 percent farmers mentioned 51 to 75 percent fruit damage, 15 percent farmers mentioned 76 to 100 percent fruit damage, about 8 percent farmers mentioned about 11 to 25 percent fruit damage and only 4 percent farmers mentioned that BSFB caused less than 10 percent fruit damage (Table-4.1.9).

Table-4.1.9. Farmers' response on extent of damage caused by BSFB infestation

Sl. No.	Extent of damage	Number of farmers [N=310]	% Response
(a)	**Extent of shoot damage due to BSFB infestation**		
	< 10%	32	10.3
	11 to 25%	256	82.6
	26 to 50%	17	5.5
	51 to 75%	5	1.6
	76 to 100%	0	0.0
	Total	**310**	**100.0**
(b)	**Extent of fruit damage due to BSFB infestation**		
	< 10%	12	3.9
	11 to 25%	24	7.7
	26 to 50%	167	53.9
	51 to 75%	62	20.0
	76 to 100%	45	14.5
	Total	**310**	**100.0**

4.1.9. Farmers' perception about the management of BSFB infestation

(a) Management options practiced by the farmers: Out of 310 respondent farmers, all of them informed that they applied chemical insecticides for the management of brinjal shoot and fruit borer followed by 85 percent farmers who used cultural practices considering collection and destruction of infested shoots and fruits, while 48 percent farmers used pheromone traps, 43 percent farmers considered IPM technique and about 36 percent farmers considered other cultural practices for the management of BSFB infestation. Whereas, about 12 percent farmers sprayed neem oil and 3 percent farmers used light trap for the management of BSFB adult (Table 4.1.10).

Table-4.1.10. Farmers' practice for the management of brinjal shoot and fruit borer

Management options	Number of farmers [N=310]	% Response
Spraying of chemical insecticides	310	100.0
Spraying of neem oil	36	11.6
Use of light trap	9	2.9
Use of Pheromone trap	148	47.7
IPM Technique	133	42.9
Collection and destruction of infested shoots and fruits	262	84.5
Other cultural management	110	35.5
Multiple response*		

**Multiple response means one respondent provided his/her response on more than one options*

(b) Application of insecticidal mixtures against BSFB

Farmers were asked to a question of whether they applied more than one insecticide as mixture in their brinjal field in controlling brinjal shoot and fruit borer, as their answers, out of 310 participated brinjal farmers, 57.4 percent of them (178) reported that they applied mixture of insecticides against BSFB. To another question of how many numbers of insecticides they mixed for a mixture to apply at a time, they replied that on an average 2.57 insecticides they mixed for a mixture that was ranged from 2 to 3 insecticides (Table-4.1.11).

Table-4.1.11. Application of insecticidal mixtures to control BSFB infestation

Sl. No.	Options & opinion	Number of farmers [N=310]	% Response
(a)	**Whether applied mixture of more than one insecticide at a time to control BSFB infestation**		
	Yes	178	57.4
	No	132	42.6
	Total	**310**	**100.0**
(b)	**Number of insecticides in a mixture applied at a time [N=178]**		
	Minimum (no.)	2	
	Maximum (no.)	3	
	Average (no.)	2.57	

(c) Frequency of insecticide applied in the brinjal field

Brinjal is very vulnerable vegetables to be attacked by various insects. Therefore, recommended insecticides spray is necessary to control insect to get better production of brinjal. These insecticides spray started from before brinjal flower (bud) until brinjal harvest. The brinjal growers frequently spray insecticides in different stages of brinjal maturation without following any standard recommendations.

The farmers participated in the survey from five sample districts were asked to a question of how much time usually they applied insecticides agaist BSFB thoughout a cropping season of brinjal. As their overall response, out of 310 sample farmers, maximum 45% of them (138) reported that they applied insecticides three days interval in their brinjal field. While 37 percent farmers applied insecticides two days interval, 11 percent applied once a day, about 6 percent farmers applied twice a day and only 3 percent farmers applied insecticides weekly in their brinjal field for the management of BSFB (Table 4.1.12). Similar type of survey findings also observed by Raza *et al.* (2018). He found that most of the farmers applied insecticide in brinjal field at three days interval.

Table-4.1.12. Farmers' response on the frequency of insecticide spraying for brinjal shoot and fruit borer infestation

Frequency	**Number of farmers [N=310]**	**% Response**
Twice a day	18	5.8
Once a day	33	10.6
Two days interval	113	36.5
Three days interval	138	44.5
Weekly	8	2.6
Total	**310**	**100.0**

Considering the district-wise distribution of farmers' response in terms of frequency of insecticide application in the brinjal field for the management of brinjal shoot and fruit borer, in case of Jashore area, highest proportion (9.7%) of farmers applied insecticides two days interval followed by once a day (4.5%), twice a day (3.2%) and three days interval (2.6%), while none of farmers applied insecticides weekly in the Jashore.

In case of Dhaka area, the highest proportion (12.9%) of farmers applied insecticides three days interval followed by two days interval (4.8%), weekly (1.3%). While the least proportion (0.3%) of farmers applied insecticides twice a day followed by once a day (0.6%).

In case of Narshingdi area, highest proportion (9%) of farmers applied insecticides three days interval followed by two days interval (7.7%), once a day (2.3%) followed by twice a day (1.0%), while none of farmers applied insecticides weekly. In case of Cumilla and Munshiganj districts, more or less similar trends of results were observed like Narshingdi in terms of frequency of insecticide application through a cropping season of brinjal aiming to control the brinjal shoot and fruit borer infestation. From these findings it was revealed that higher frequency of insecticides application was practiced by the farmers of Jashore than that of other districts (Table-4.1.13).

Table-4.1.13. Region-wise distribution of farmers by frequency of insecticide application to control BSFB infestation

Frequency of application	Percent farmers' response by frequency of insecticide application					
	Jashore	**Dhaka**	**Narshingdi**	**Cumilla**	**Munshiganj**	**Total**
Twice a day	3.2	0.3	1.0	1.0	0.3	5.8
Once a day	4.5	0.6	2.3	1.9	1.3	10.6
Two days interval	9.7	4.8	7.7	7.4	6.8	36.5
Three days interval	2.6	12.9	9.0	9.4	10.6	44.5
Weekly	0.0	1.3	0.0	0.3	1.0	2.6
Total	**20.0**	**20.0**	**20.0**	**20.0**	**20.0**	**100.0**
N	**62**	**62**	**62**	**62**	**62**	**310**

(d) Source of information regarding BSFB management

To a question of from which source(s) the farmers usually obtain the information regarding BSFB management, as their answers, out of 310 farmers, maximum 72.3 percent farmers reported that they usually obtained information about the management of brinjal shoot and fruit borer from the pesticide dealer, while 41.3 percent mentioned they obtained information from Sub-Assistant Agriculture Officer (SAAO), the Agricultural Block Level DAE Official. This response was followed by Farmers' own experience (31.6%), neighboring farmers (23.5%). Other sources were Agriculture Extension Officer (AEO) and/or Upazila Agriculture Officer (UAO), Pesticide Company People, social media and Radio/TV as reporte by 3.9, 2.3, 2.9 and 1.3 percent farmers, respectively (Table-4.1.14).

Table-4.1.14. Source of information obtained regarding BSFB management

Source	**Number of farmers [N=310]**	**% Response**
Neighboring farmers	73	23.5
Previous experience	98	31.6
Pesticide dealer	224	72.3
SAAO	128	41.3
AEO/UAO	12	3.9
Company people	7	2.3
Social media	9	2.9
Radio/TV	4	1.3
Multiple response*		

**Multiple response means one respondent provided his/her response on more than one options*

(e) Yield increased due to insecticide application agaist BSFB: To a question of whether the yield of brinjal increased due to application of insecticides against brinjal shoot and fruit borer, as their answers, out of 310 farmers, all (100.0%) of them reported that the brinjal fruit yield was increased due to application of insecticides in controlling brinjal shoot and fruit borer infestation. To another question of approximately what proportion of brinjal fruit yield was increased due to application of insecticides, a large proportion (75%) of farmers mentioned that appximately 26-50% brinjal fruit yield was increased, while about 22 percent mentioned approximately 11-25% brinjal fruit yield was increased, 2 percent farmers mentioned less than 10% and 1.0 percent farmers (3) mentioned 51-75% brinjal fruit yield was increased due to application of insecticides against brinjal shoot and fruit borer infestation (Table-4.1.15).

Table-4.1.15. Farmers' response on extent of damage caused by BSFB infestation

Sl. No.	Options & opinions	Number of farmers [N=310]	% Response
(a)	**Whether the yield of brinjal increased due to application of insecticides against BSFB?**		
	Yes	310	100.0
	No	0	0.0
	Total	**310**	**100.0**
(b)	**Proportion (%) of brinjal fruit yield increased**		
	< 10%	7	2.3
	11 to 25%	68	21.9
	26 to 50%	232	74.8
	51 to 75%	3	1.0
	76 to 100%	0	0.0
	Total	**310**	**100.0**

4.1.10. Environmental hazards due to insecticide application

(a) Concerned about environmental hazards of insecticide application: Farmers were asked a question of whether they were concerned about the hazardous effect on environment due to insecticidal application against brinjal shoot and fruit borer infestation. As their answers, out of 310 sample farmers, about 84 percnet of them (261) admitted that they were well known about the hazardous effect of insecticides on the environment (Figure 4.1.5). Raza *et al.* (2018) also found similar type of response from the brinjal growers. He found that about 33% brinjal growers are little consious about side effect of insecticides.

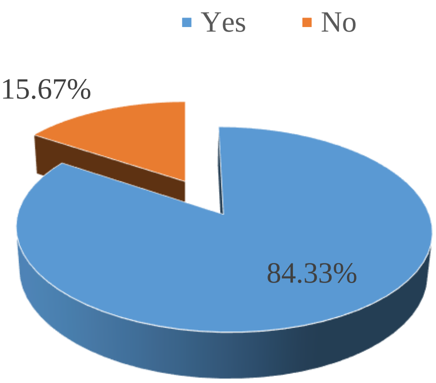


Figure 4.1.5. Farmers' response on the hazardous effect of insecticides on environment during BSFB management

(b) Kinds of hazardous effect of insecticides on environment

To another question of what kind of hazards usually occurred due to application of insecticides aiming to control the brinjal shoot and fruit borer infestation. As response, farmers provided multiple answers, where out of 310 sample farmers, about 77.0 percent farmers informed that the spraying of insecticides polluted water as most hazardous effect, followed by residual toxicity to brinjal (51%), health hazards (36%), hazardous effect on fisheries (33%), disruption of natural enemies (25%), soil pollution (25%) and air pollution (16%) (Table 4.1.16).

Table-4.1.16. Kinds of hazardous effect caused by insecticide application

Kinds of hazard	Number of farmers [N=310]	% Response
Water pollution	231	77.0
Soil pollution	74	24.7
Fisheries hazards	98	32.7
Air pollution	48	15.5
Residual toxicity to brinjal	157	50.7
Disruption of natural enemies	78	25.2
Health hazards	110	35.5
Multiple response*		

**Multiple response means one respondent provided his/her response on more than one options*

4.1.11. Hazards free management of BSFB

(a) Concerned about hazards free management of BSFB: To a question of whether the farmers were concerned about the hazards free management of brinjal shoot and fruit borer infestation, as their answers, out of 310 sample farmers, 87.4 percent (271) of them reported that they were well known about the hazard free management of BSFB (Table-4.1.17).

Table-4.1.17. Distribution of farmers by concerned about hazards free management of BSFB infestation

Options & opinions	Number of farmers [N=310]	% Response
Yes	271	87.4
No	39	12.6
Total	**310**	**100.0**

(b) Pheromone trap as hazard free management: To a question of whether the farmers were concerned about the pheromone trap as hazards free management option against brinjal shoot and fruit borer, as their answers, out of 310 sample farmers, 62.3 percent (193) of them reported that they were well known about the pheromone trap as hazard free management of BSFB (Table-4.1.18). To another question of whether the concerned farmers used pheromone traps at the aim of hazard free management of brinjal shoot and fruit borer in their own brinjal field, as their answers, out of 193 farmers, about 77 percent (148) farmers used pheromone traps in their own brinjal field for the management of brinjal shoot and fruit borer (Table-4.1.18).

Table-4.1.18. Distribution of farmers by concerned about hazards free management of BSFB infestation

Sl. No.	Options & opinions	Number of farmers [N=310]	% Response
(a)	**Whether farmers concerned about pheromone trap as hazards free management option against BSFB?**		
	Yes	193	62.3
	No	117	37.7
	Total	**310**	**100.0**
(b)	**Whether farmers utilized pheromone traps against BSFB? [N=193]**		
	Yes	148	76.7
	No	45	23.3
	Total	**193**	**100.0**

(c) Source of pheromone lure obtained: Farmers who used the pheromone traps against BSFB were also asked a question of from which source(s) they obtained pheromone lures what they used, as their answers, out of 148 farmers, about 66.0 percent farmers reported that they obtained pheromone lures from pesticide dealer, while 39 percent farmers obtained from pesticide company people and about 9 percent farmers obtained pheromone lures from field level DAE officials viz. Sub-Assistant Agriculture Officer (SAAO); Upazaila Agriculture Officer (UAO) (Table-4.1.19).

Table-4.1.19. Farmers' response about the source of obtaining pheromone lures

Source	Number of farmers [N=148]	% Response
Pesticide dealer	98	66.2
DAE officials (SAAO/UAO)	13	8.8
Pesticide company people	57	38.5
Multiple response*		

**Multiple response means one respondent provided his/her response on more than one options*

(d) Outcome of pheromone trap used: To a question of whether obtained expected outcome of pheromone trap used in terms of reducing BSFB infestation, out of 148 farmers who used pheromone trap, about 82 percent of them (121) reported that they obtained expected result by using pheromone trap in their brinjal field. Conversely, about 18 percent farmers claimed that they did not get expected results of pheromone traps in reducing BSFB infestation (Figure 4.1.6).

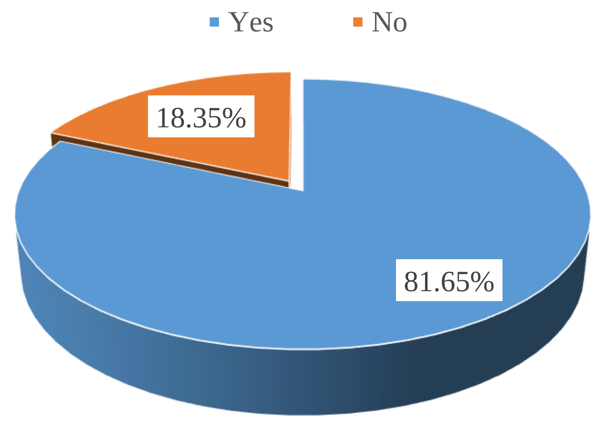


Figure 4.1.6. Farmers' response on getting expected result for using pheromone traps in their brinjal field against BSFB

The farmers also mentioned the reasons for not getting expected result by using pheromone trap against BSFB, where out of 27 farmers, about 48 percent farmers (13) reported that they did not get desired result as because of water used in the trap became dry, while 41 percent farmers mentioned poor quality of lure and about 30 percent farmers mentioned heavy rainfall and storm constrained the expected results of using pheromone traps against brinjal shoot and fruit borer (Table-4.1.20).

Table-4.1.20. Reasons for not getting expected results from pheromone trap

Reasons	**Number of farmers [N=27]**	**% Response**
Water become dry	13	48.1
Heavy rain and storm	8	29.6
Poor quality of lure	11	40.7
Multiple response*		

**Multiple response indicates one respondent provided his opinion on more than one answer of given options*

Experiment-2: Screening of commonly cultivated brinjal varieties against brinjal shoot and fruit borer

The present study on Screeing of brinjal varieties for resistance/tolerance against brinjal shoot and fruit borer was conducted in the Experimental Field of the Department of Entomology at Sher-e-Bangla Agricultural University (SAU), Dhaka during Rabi Season (October 2016 to May 2017). The data were collected on various parameters such as leaf length, pith thickness, number of healthy and infested shoot and fruit per plant, weight of healthy and infested fruits per plant, number of bore per infested fruit, number of larvae per infested fruit, trichome hair desnsity, etc. The findings of the present study have been discussed and presented with interpretations in the following sub-headings:

4.2. Infestation level

4.2.1. Shoot infestation

The significant variations were observed among different brinjal varieties in terms of percent shoot infestation at vegetative, early fruiting, mid fruiting and late fruiting stages of brinjal in the field against brinjal shoot and fruit borer (Table 4.2.1). In case of vegetative stage of brinjal, the highest shoot infestation (27.33%) was recorded in V_{13} (BARI Hybrid Begun-4) which was statistically different from all other varieties followed by V_{11} (BARI Begun-9), V_{10} (BARI Begun-8), V_{12} (BARI Begun-10), V_7 (BARI Begun-5), V_8 (BARI Begun-6), V_6 (BARI Begun-4) and V_9 (BARI Begun-7) those contributed 26.58, 23.66, 22.87, 20.37, 18.32, 17.34 and 14.71% shoot infestation, respectively. On the other hand, the lowest shoot infestation (2.57%) was recorded in V_1 (BARI Bt Begun-1), which was statistically different from all other varieties followed by V_4 (BARI Bt Begun-4), V_3 (BARI Bt Begun-3), V_2 (BARI Bt Begun-2) and V_5 (BARI Begun-1) those manifested 2.73, 3.29, 3.34 and 12.81% shoot infestation, respectively. More or less similar trends of results were recorded in terms of percent shoot infestation at early, mid, and late fruiting stages of brinjal, where the highest shoot infestations were recorded in V_{13} (BARI Hybrid Begun-4). Conversely the lowest shoot infestations were observed V_1 (BARI Bt Begun-1). With increasing growth stages of the brinjal, the percent shoot infestation was also increased with the increase of the ages of the plants, where minimum shoot infestation was recorded at vegetative stage for all brinjal varieties and maximum shoot infestation at late fruiting stage. As a result, the order of shoot infestation for all varieties of brinjal is mid fruiting stage > early fruiting stage > late fruiting stage > vegetative stage.

Considering the mean shoot infestation, the highest shoot infestation (29.78%) was recorded in V_{13} (BARI Hybrid Begun-4) which was statistically different from all other varieties followed by V_8 (BARI Begun-6), V_{11} (BARI Begun-9), V_7 (BARI Begun-5), V_9 (BARI Begun-7), V_{12} (BARI Begun-10), V_{10} (BARI Begun-8) and V_6 (BARI Begun-4) and those contributed 26.80, 25.80, 25.45, 23.76, 21.54, 21.34 and 19.89% shoot infestation, respectively. On the other hand, the lowest shoot infestation (3.37%) was recorded in V_1 (BARI Bt Begun-1), which was statistically different from all other varieties followed by V_4 (BARI Bt Begun-4), V_2 (BARI Bt Begun-2), V_3 (BARI Bt Begun-3) and V_5 (BARI Begun-1) and those manifested 4.74, 5.49, 6.79 and 18.28% shoot infestation, respectively.

From the above findings it was revealed that V_{13} (BARI Hybrid Begun-4) and V_8 (BARI Begun-6) performed as the most susceptible brinjal varieties in terms of percent shoot infestation (29.78 and 26.80%, respectively), whereas the V_1 (BARI Bt Begun-1) performed as the least susceptible varieties in terms of shoot infestation (3.37%) due to attack of brinjal shoot and fruit borer. As a result, the trends of least preferable brinjal varieties in terms of percent shoot infestation is V_1 (BARI Bt Begun-1) > V_4 (BARI Bt Begun-4) > V_2 (BARI Bt Begun-2) > V_3 (BARI Bt Begun-3) > V_5 (BARI Begun-1 (Uttara)) > V_6 (BARI Begun-4 (Kajla)) > V_{10} (BARI Begun-8) > V_{12} (BARI Begun-10 (Bholanath)) > V_9 (BARI Begun-7 (Singnath)) > V_7 (BARI Begun-5 (Nayantara)) > V_{11} (BARI Begun-9 (Dohazari)) > V_8 (BARI Begun-6 (Ishurdi local)) > V_{13} (BARI Hybrid Begun-4). Similar results were also reported by several researchers. Islam (2014) found the shoot infestation caused by BSFB ranged from 1.18 to 5.50%. Panda (1999) reported in their findings that shoot infestation varied from 1.61 to 44.11%.

Table 4.2.1. Shoot infestation caused by brinjal shoot and fruit borer in different brinjal varieties

Variety	% shoot infestation				
	Vegetative stage	Early fruiting stage	Mid fruiting stage	Late fruiting stage	Mean infestation
V_1	2.57 k	2.83 l	3.37 m	3.67 m	3.37 m
V_2	3.34 j	4.20 j	5.49 k	6.38 j	5.49 k
V_3	3.29 j	5.80 i	6.79 j	4.36 l	6.79 j
V_4	2.73 k	3.76 k	4.74 l	5.59 k	4.74 l
V_5	12.81 i	15.14 h	18.28 i	14.36 i	18.28 i
V_6	17.34 fg	20.26 f	19.89 h	19.42 h	19.89 h
V_7	20.37 e	22.77 e	25.45 d	21.50 g	25.45 d
V_8	18.32 f	20.77 f	26.80 b	25.50 d	26.80 b
V_9	14.71 h	17.59 g	23.76 e	26.37 c	23.76 e
V_{10}	23.66 c	26.55 c	21.34 g	25.33 e	21.34 g
V_{11}	26.58 b	28.87 ab	25.80 c	27.40 b	25.80 c
V_{12}	22.87 cd	25.48 d	21.54 f	23.91 f	21.54 f
V_{13}	27.33 a	29.57 a	29.78 a	28.45 a	29.78 a
CV (%)	0.56	0.88	0.78	2.43	6.33
$LSD_{(0.05)}$	1.17	0.96	3.73	0.05	0.93

[In columns, each mean is the average of three replicates and the same letter with means indicate the statistically similar with each other at 5% level of significance with DMRT.

Here, V_1= BARI Bt Begun-1, V_2= BARI Bt Begun-2, V_3= BARI Bt Begun-3, V_4= BARI Bt Begun-4, V_5= BARI Begun-1 (Uttara), V_6= BARI Begun-4 (Kajla), V_7= BARI Begun-5 (Nayantara), V_8= BARI Begun-6 (Ishurdi local), V_9= BARI Begun-7 (Singnath), V_{10}= BARI Begun-8, V_{11}= BARI Begun-9 (Dohazari), V_{12}= BARI Begun-10 (Bholanath), V_{13}= BARI Hybrid Begun-4]

4.2.2. Fruit infestation

The significant variations were observed among different brinjal varieties in terms of percent fruit infestation by number and weight at early fruiting, mid fruiting and late fruiting stages of brinjal in the field against brinjal shoot and fruit borer (Table 4.2.2 and 4.2.3).

(a) Fruit infestation by number

In case of early fruiting stage of brinjal, the highest fruit infestation by number (29.89%) was recorded in V_{13} (BARI Hybrid Begun-4) which was statistically different from all other varieties followed by V_9 (BARI Begun-7), V_{11} (BARI Begun-9), V_8 (BARI Begun-6), V_6 (BARI Begun-4), V_{10} (BARI Begun-8), V_{12} (BARI Begun-10) and V_7 (BARI Begun-5) those contributed 28.75, 28.34, 27.32, 26.90, 23.37, 21.89 and 21.83% fruit infestation, respectively. On the other hand, the lowest fruit infestation by number (2.38%) was recorded in V_1 (BARI Bt Begun-1), which was statistically different from all other varieties followed by V_4 (BARI Bt Begun-4), V_3 (BARI Bt Begun-3), V_2 (BARI Bt Begun-2) and V_5 (BARI Begun-1) those manifested 2.65, 3.55, 4.89 and 15.67% fruit infestation, respectively. More or less similar trends of results were recorded in terms of percent fruit infestation at mid and late fruiting stages of brinjal, where the highest fruit infestations were recorded in V_{13} (BARI Hybrid Begun-4). Conversely the lowest fruit infestations were observed V_1 (BARI Bt Brinjal-1). In case of increasing growth stages of the brinjal, the percent fruit infestation by number was increased with the increase of the ages of the plants, where minimum fruit infestation was recorded at vegetative stage for all brinjal varieties and maximum fruit infestation at late fruiting stage. As a result, the order of fruit infestation by number for all varieties of brinjal is mid fruiting stage > early fruiting stage > late fruiting stage.

Considering the mean fruit infestation by number, the highest fruit infestation by number (35.32%) was recorded in V_{13} (BARI Hybrid Begun-4) which was statistically different from all other varieties followed by V_9 (BARI Begun-7), V_{11} (BARI Begun-9), V_8 (BARI Begun-6), V_6 (BARI Begun-4), V_{10} (BARI Begun-8), V_{12} (BARI Begun-10) and V_7 (BARI Begun-5) those contributed 29.67, 29.40, 28.80, 27.37, 24.38, 22.75 and 22.67% fruit infestation, respectively. On the other hand, the lowest fruit infestation by number (3.77%) was recorded in V_1 (BARI Bt Begun-1), which was statistically different from all other varieties followed by V_4 (BARI Bt Begun-4), V_3 (BARI Bt

Begun-3), V_2 (BARI Bt Begun-2) and V_5 (BARI Begun-1) those manifested 3.89, 4.33, 5.71 and 17.88% fruit infestation by number, respectively.

From the above findings it was revealed that V_{13} (BARI Hybrid Begun-4) performed as the most suitable brinjal varieties in terms of percent fruit infestation by number (35.32%), whereas the V_1 (BARI Bt Begun-1) performed as the least suitable varieties in terms of fruit infestation by number (3.77%) due to attack of brinjal shoot and fruit borer.

Table 4.2.2. Fruit infestation by number due to brinjal shoot and fruit borer attack in different brinjal varieties

Treatment	% Fruit infestation by number			
	Early fruiting stage	Mid fruiting stage	Late fruiting stage	Mean infestation
V_1	2.38 j	3.37 l	4.46 l	3.77 l
V_2	4.89 h	5.49 ij	6.34 j	5.71 i
V_3	3.55 i	6.79 i	4.66 k	4.33 j
V_4	2.65 j	4.74 k	4.74 k	3.89 k
V_5	15.67 g	18.28 h	14.34 i	17.88 h
V_6	26.90 cd	25.45 d	28.67 d	27.37 e
V_7	21.83 f	19.89 g	25.34 h	22.67 g
V_8	27.32 c	26.80 b	26.87 e	28.80 d
V_9	28.75 b	23.76 e	29.34 c	29.67 b
V_{10}	23.37 e	21.34 f	25.77 g	24.38 f
V_{11}	28.34 b	25.80 c	31.67 b	29.40 c
V_{12}	21.89 f	21.54 f	26.38 f	22.75 g
V_{13}	29.89 a	29.78 a	38.36 a	35.32 a
CV (%)	0.77	0.96	0.08	0.68
$LSD_{(0.05)}$	1.06	1.37	0.05	0.85

[In columns, each mean is the average of three replicates and the same letter with means indicate the statistically similar with each other at 5% level of significance with DMRT.

Here, V_1= BARI Bt Begun-1, V_2= BARI Bt Begun-2, V_3= BARI Bt Begun-3, V_4= BARI Bt Begun-4, V_5= BARI Begun-1 (Uttara), V_6= BARI Begun-4 (Kajla), V_7= BARI Begun-5 (Nayantara), V_8= BARI Begun-6 (Ishurdi local), V_9= BARI Begun-7 (Singnath), V_{10}= BARI Begun-8, V_{11}= BARI Begun-9 (Dohazari), V_{12}= BARI Begun-10 (Bholanath), V_{13}= BARI Hybrid Begun-4]

As a result, the trends of least preferable brinjal varieties in terms of percent fruit infestation by number is V_1 (BARI Bt Brinjal-1) > V_4 (BARI Bt Brinjal-4) > V_3 (BARI Bt Brinjal-3) > V_2 (BARI Bt Brinjal-2) > V_5 (BARI Begun-1 (Uttara)) > V_7 (BARI Begun-5 (Nayantara)) > V_{12} (BARI Begun-10 (Bholanath)) > V_{10} (BARI Begun-8) > V_6 (BARI Begun-4 (Kajla)) > V_8 (BARI Begun-6 (Ishurdi local)) > V_{11} (BARI Begun-9 (Dohazari)) > V_9 (BARI Begun-7 (Singnath)) > V_{13} (BARI Hybrid Begun-4). About similar results were also reported by several researchers. Islam (2014) found the shoot infestation caused by BSFB ranged from 3.54% to 27.45%.

(b) Fruit infestation by weight

In case of early fruiting stage of brinjal, the highest fruit infestation by weight (38.37%) was recorded in V_{13} (BARI Hybrid Begun-4) which was statistically different from all other varieties followed by V_{11} (BARI Begun-9), V_9 (BARI Begun-7), V_6 (BARI Begun-4), V_8 (BARI Begun-6), V_{12} (BARI Begun-10), V_{10} (BARI Begun-8) and V_7 (BARI Begun-5) those contributed 31.71, 29.36, 28.69, 26.91, 26.33, 25.73 and 25.34% fruit infestation, respectively. On the other hand, the lowest fruit infestation by weight (4.47%) was recorded in V_1 (BARI Bt Begun-1), which was statistically different from all other varieties followed by V_4 (BARI Bt Begun-4), V_3 (BARI Bt Begun-3), V_2 (BARI Bt Begun-2) and V_5 (BARI Begun-1) those manifested 4.66, 4.68, 6.33 and 14.33% fruit infestation, respectively. More or less similar trends of results were recorded in terms of percent fruit infestation by weight at mid and late fruiting stages of brinjal, where the highest fruit infestations were recorded in V_{13} (BARI Hybrid Begun-4). Conversely the lowest fruit infestations were observed in V_1 (BARI Bt Brinjal-1). In case of increasing growth stages of the brinjal, the percent fruit infestation by weight was increased with the increase of the ages of the plants, where minimum fruit infestation was recorded at early fruiting stage for all brinjal varieties and maximum fruit infestation at late fruiting stage. As a result, the order of fruit infestation by weight for all varieties of brinjal is early fruiting stage > mid fruiting stage > late fruiting stage.

Considering the mean fruit infestation by weight, the highest fruit infestation by weight (47.52%) was recorded in V_{13} (BARI Hybrid Begun-4) which was statistically different from all other varieties followed by V_{11} (BARI Begun-9), V_{12} (BARI Begun-10), V_7 (BARI Begun-5), V_8 (BARI Begun-6), V_9 (BARI Begun-7), V_6 (BARI Begun-4) and

V_{10} (BARI Begun-8) and those contributed 33.12, 31.67, 31.62, 30.65, 30.59, 29.32 and 26.49% fruit infestation, respectively. On the other hand, the lowest fruit infestation by weight (4.57%) was recorded in V_1 (BARI Bt Begun-1), which was statistically different from all other varieties followed by V_3 (BARI Bt Begun-3), V_4 (BARI Bt Begun-4), V_2 (BARI Bt Begun-2) and V_5 (BARI Begun-1) those manifested 5.53, 5.63, 6.66 and 15.94% fruit infestation by weight, respectively.

Table 4.2.3. Fruit infestation by weight due to brinjal shoot and fruit borer attack in different brinjal varieties

Treatment	% Fruit infestation by weight			
	Early fruiting stage	Mid fruiting stage	Late fruiting stage	Mean infestation
V_1	4.47 i	4.57 j	6.37 j	4.57 j
V_2	6.33 h	6.66 h	8.38 h	6.66 h
V_3	4.68 i	5.53 i	7.36 i	5.53 i
V_4	4.66 i	5.63 i	6.69 ij	5.63 i
V_5	14.33 g	15.94 g	19.73 g	15.94 g
V_6	28.69 cd	29.32 e	31.70 f	29.32 e
V_7	25.34 f	31.62 c	34.71 d	31.62 c
V_8	26.91 e	30.65 d	36.17 c	30.65 cd
V_9	29.36 c	30.49 d	37.47 b	30.59 cd
V_{10}	25.73 f	26.49 f	31.57 f	26.49 f
V_{11}	31.71 b	33.12 b	34.66 d	33.12 b
V_{12}	26.33 e	31.67 c	33.67 de	31.67 c
V_{13}	38.37 a	47.52 a	51.57 a	47.52 a
CV (%)	2.65	2.78	3.42	3.77
$LSD_{(0.05)}$	2.44	2.13	1.98	1.63

[In columns, each mean is the average of three replicates and the same letter with means indicate the statistically similar with each other at 5% level of significance with DMRT.

Here, V_1= BARI Bt Begun-1, V_2= BARI Bt Begun-2, V_3= BARI Bt Begun-3, V_4= BARI Bt Begun-4, V_5= BARI Begun-1 (Uttara), V_6= BARI Begun-4 (Kajla), V_7= BARI Begun-5 (Nayantara), V_8= BARI Begun-6 (Ishurdi local), V_9= BARI Begun-7 (Singnath), V_{10}= BARI Begun-8, V_{11}= BARI Begun-9 (Dohazari), V_{12}= BARI Begun-10 (Bholanath), V_{13}= BARI Hybrid Begun-4]

From the above findings it was revealed that V_{13} (BARI Hybrid Begun-4) performed as the most suitable brinjal varieties in terms of percent fruit infestation by weight (47.52%), whereas the V_1 (BARI Bt Begun-1) performed as the least suitable varieties in terms of fruit infestation by weight (4.57%) due to attack of brinjal shoot and fruit borer.

As a result, the trends of least preferable brinjal varieties in terms of percent fruit infestation by weight is V_1 (BARI Bt Brinjal-1) > V_3 (BARI Bt Brinjal-3) > V_4 (BARI Bt Brinjal-4) > V_2 (BARI Bt Brinjal-2) > V_5 (BARI Begun-1 (Uttara)) > V_{10} (BARI Begun-8) > V_6 (BARI Begun-4 (Kajla)) > V_9 (BARI Begun-7 (Singnath)) > V_8 (BARI Begun-6 (Ishurdi local)) > V_7 (BARI Begun-5 (Nayantara)) > V_{12} (BARI Begun-10 (Bholanath)) > V_{11} (BARI Begun-9 (Dohazari)) > V_{13} (BARI Hybrid Begun-4). About similar results were also reported by several researchers. Islam (2014) found the fruit infestation caused by BSFB ranged from 2.74% to 28.10%.

4.2.3. Infestation intensity

The effects of different brinjal varieties on the infestation intensity expressed in terms of fruits having number of bore per fruits corresponding to any of 3 scales such as scale 1 comprised with 1-2 bores/fruit and designated as low infestation intensity; scale 2 comprised with 3-4 bores/fruit and designated as moderate infestation intensity; while the scale 3 comprised with more than 5 bores/fruit and designated as high infestation intensity have been presented in Table 4.2.4.

In case of scale 1 infestation intensity, the highest frequency of low infestation intensity fruits (8.89 per plot) was observed in V_{13}, which was statistically different from all other varieties followed by V_{12}, V_6, V_{10}, V_{11}, V_5 and V_7, whereas the minimum frequency of low infestation intensity fruits was observed in V_1 (1.51 per plot) which was different from all other varieties followed by V_2, V_4, V_8, V_9 and V_3.

In case of scale 2 infestation intensity, the highest frequency of moderate infestation intensity fruits (6.38 per plot) was observed in V_{13}, which was statistically different from all other varieties followed by V_{12}, V_6, V_{10}, V_{11}, V_5 and V_7, whereas the minimum frequency of low infestation intensity fruits was observed in V_1 (1.51 per plot) which was different from all other varieties followed by V_2, V_4, V_8, V_9 and V_3. More or less similar trend of the frequency of infestation intensity fruits was also observed in case of scale 3, where the highest frequency of high infestation intensity fruits (3.29 per plot) was observed in V_{13}, which was statistically different from all other varieties followed by V_{10}, V_{9}, V_{12}, V_{6}, V_{7} and V_{11}, whereas the minimum frequency of low infestation intensity fruits was observed in V_1 (0.38 per plot) which was different from all other varieties followed by V_4, V_2, V_8, V_3 and V_5.

Table 4.2.4. Fruit infestation intensity (no. of bore/fruit) caused by brinjal shoot and fruit borer in different brinjal varieties

Treatment	Infestation intensity (number of bores/ fruit)		
	Scale 1 (1-2 bores/fruit)	Scale 2 (3-4 bores/fruit)	Scale 3 (>5 bores/fruit)
V_1	1.51 j	0.78 g	0.38 i
V_2	1.78 i	1.40 e	0.56 h
V_3	2.37 g	1.81 d	0.91 g
V_4	2.12 h	1.70 d	0.51 h
V_5	2.83 f	1.08 f	1.15 f
V_6	5.18 c	2.64 c	1.77 d
V_7	2.77 f	1.92 d	1.62 e
V_8	2.15 h	2.57 c	0.85 g
V_9	2.33 h	1.82 d	1.87 c
V_{10}	4.56 d	2.78 c	2.64 b
V_{11}	3.12 e	2.77 c	1.62 e
V_{12}	5.47 b	3.55 b	1.92 c
V_{13}	8.89 a	5.38 a	3.29 a
CV (%)	4.85	7.82	11.23
$LSD_{0.05}$	0.47	0.41	0.43

[In columns, each mean is the average of three replicates and the same letter with means indicate the statistically similar with each other at 5% level of significance with DMRT.

Here. V_1= BARI Bt Begun-1, V_2= BARI Bt Begun-2, V_3= BARI Bt Begun-3, V_4= BARI Bt Begun-4, V_5= BARI Begun-1 (Uttara), V_6= BARI Begun-4 (Kajla), V_7= BARI Begun-5 (Nayantara), V_8= BARI Begun-6 (Ishurdi local), V_9= BARI Begun-7 (Singnath), V_{10}= BARI Begun-8, V_{11}= BARI Begun-9 (Dohazari), V_{12}= BARI Begun-10 (Bholanath), V_{13}= BARI Hybrid Begun-4]

From these findings it was revealed that, due to infestation caused by BSFB, the least preferred (resistant) brinjal varieties such as V_1 (BARI Bt Begun-1) manifested low infestation intensity on fruits and the most preferred (susceptible) brinjal varieties such as V_{13} (BARI Hybrid Begun-4) evident high infestation intensity on fruits was found in scale 1, scale 2 and scale 3 infestation. Similar results were also reported by several researchers. Islam (2014) found that BARI brinjal 6 manifested low infestation intensity (scale 1) on fruits and the most preferred (susceptible) brinjal varieties such as BARI brinjal 7 evident high infestation intensity (scale 3) on fruits.

4.2.4. Yield attributes

The significant variations were observed among different brinjal varieties in terms of plant related yield attributes such as number of branches per plant and number of leaves per plant as well as fruit related yield attributes such as number of fruits per plant, fruit length, fruit girth, single fruit weight throughout the growing period of brinjal in the field (Table 4.2.5 and 4.2.6).

(a) Plant related yield attributes

The significant variations were observed among different brinjal varieties in terms of number of branches per plant and number of leaves per plant throughout the growing period of eggplants in the field (Table 4.2.5).

Number of branches per plant

The highest number of branches per plant (12.33) was observed V_{13} (BARI Hybrid Begun-4), which was significantly different from all other varieties followed by V_{11} (BARI Begun-9), V_{12} (BARI Begun-10), V_7 (BARI Begun-5), V_8 (BARI Begun-6), V_9 (BARI Begun-7) and V_6 (BARI Begun-4) which contributed 11.86, 11.25, 10.65, 10.23, 9.85 and 9.56 branches per plant, respectively. On the other hand, the lowest number of branches per plant (8.16) was observed in V_1 (BARI Bt Begun-1) which was significantly different from all other varieties followed by V_3 (BARI Bt Begun-3), V_4 (BARI Bt Begun-4), V_2 (BARI Bt Begun-2), V_5 (BARI Begun-1) and V_{10} (BARI Begun-8) which contributed 8.55, 8.95, 9.06, 9.24 and 9.32 branches per plant, respectively.

Number of leaves per plant

In terms of leaf number per plant, the highest number of leaves per plant (86.00) was observed in V_{13} (BARI Hybrid Begun-4), which was significantly similar with V_{11} (BARI Begun-9), and followed by V_{12} (BARI Begun-10), V_7 (BARI Begun-5), V_8 (BARI Begun-6), V_9 (BARI Begun-7) and V_6 (BARI Begun-4) which contributed 83.67, 78.00, 77.67, 77.33, 73.00 and 72.67 leaves per plant, respectively. On the other hand, lowest number of leaves per plant (58.33) was observed in V_1 (BARI Bt Begun-1) which was significant from all other varieties followed by V_3 (BARI Bt Begun-3), V_4 (BARI Bt Begun-4), V_2 (BARI Bt Begun-2), V_5 (BARI Begun-1) and V_{10} (BARI Begun-8) which contributed 62.33, 62.67, 63.00, 65.67 and 66.33 leaves per plant, respectively.

Table 4.2.5. Number of branches and leaves per plant in different brinjal varieties

Treatment	Plant related yield attributes	
	Branch (No./plant)	**Leaf (No./plant)**
V_1	8.16 m	58.33 g
V_2	9.06 j	63.00 ef
V_3	8.55 l	62.33 f
V_4	8.95 k	62.67 f
V_5	9.24 i	65.67 de
V_6	9.56 g	72.67 c
V_7	10.65 d	77.67 b
V_8	10.23 e	77.33 b
V_9	9.85 f	73.00 c
V_{10}	9.32 h	66.33 d
V_{11}	11.86 b	83.67 a
V_{12}	11.25 c	78.00 b
V_{13}	12.33 a	86.00 a
CV (%)	0.27	2.28
$LSD_{0.05}$	0.05	2.74

[In columns, each mean is the average of three replicates and the same letter with means indicate the statistically similar with each other at 5% level of significance with DMRT.

Here, V_1= BARI Bt Begun-1, V_2= BARI Bt Begun-2, V_3= BARI Bt Begun-3, V_4= BARI Bt Begun-4, V_5= BARI Begun-1 (Uttara), V_6= BARI Begun-4 (Kajla), V_7= BARI Begun-5 (Nayantara), V_8= BARI Begun-6 (Ishurdi local), V_9= BARI Begun-7 (Singnath), V_{10}= BARI Begun-8, V_{11}= BARI Begun-9 (Dohazari), V_{12}= BARI Begun-10 (Bholanath), V_{13}= BARI Hybrid Begun-4]

From these findings it was revealed that the brinjal variety V_{13} was mostly preferred by BSFB produced the highest number of branches and leaves per plant, while the least preferred brinjal variety V_1 produced the lowest number of branches and leaves per plant. Earlier, it was observed that variety V_1 (BARI Bt Begun-1) which possessed lowest number of infestations in terms shoot infestation, fruit infestation by number and weight produced the lowest number of branches and leaves per plant. It was also inferred from these findings that the bushy and shady varieties of brinjal manifested by higher number of branches and leaves werer much preferred by the brinjal shoot and fruit borer for infestation on shoots and fruits. Similar results were also reported by several researchers. Amin *et al.,* (2014) reported in their findings that the lowest number of leaves and branch per plant the lowest is the infestation by brinjal shoot and fruit borer.

(b) Fruit related yield attributes

The significant variations were observed among different brinjal varieties in terms of fruit related yield attributes such as number of fruits per plant, fruit length, fruit girth, single fruit weight throughout the growing period of brinjal in the field (Table 4.2.6).

Number of fruits per plant

Table 4.2.6 depicted that different fruits per plant was greatly influenced by the effect of brinjal shoot and fruit borer. Results revealed that highest number of fruits per plant (66.33) was observed in V_2 (BARI Bt Begun-2) which was significantly different from all other varieties followed by V_1 (BARI Bt Begun-1), V_{13} (BARI Hybrid Begun-4), V_7 (BARI Begun-5), V_5 (BARI Begun-1) and V_3 (BARI Bt Begun-3) which contributed 45.67, 38.33, 27.67, 26.33 and 24.33 fruits per plant, respectively. Similarly, the lowest number of fruits per plant (5.33) has been observed in V_6 (BARI Begun-4) which was significantly similar with V_8 (BARI Begun-6), V_{11} (BARI Begun-9) and V_9 (BARI Begun-7), and followed by V_{12} (BARI Begun-10), V_4 (BARI Bt Begun-4) and V_{10} (BARI Begun-8) that contributed 5.33, 6.33, 6.67, 17.67, 22.33 and 22.33 fruits per plant, respectively. As a result, in case of number of fruits per plant the following trend was found: V_2 (BARI Bt Begun-2)> V_1 (BARI Bt Begun-1)> V_{13} (BARI Hybrid Begun-4)> V_7 (BARI Begun-5 (Nayantara))> V_5 (BARI Begun-1 (Uttara)) > V_3 (BARI Bt Begun-3) > V_4 (BARI Bt Begun-4) > V_{10} (BARI Begun-8) > V_{12} (BARI Begun-10

(Bholanath)) > V_9 (BARI Begun-7 (Singnath)) > V_{11} (BARI Begun-9 (Dohazari)) > V_8 (BARI Begun-6 (Ishurdi local)) > V_6 (BARI Begun-4 (Kajla)).

Fruit length

The result obtained from Table 4.2.6 showed that single fruit length had different influence in terms of different varieties. The highest single fruit length (25.34 cm) has been reported in case of V_{12} (BARI Begun-10) which was statistically different from other varieties and followed by V_9 (BARI Begun-7), V_{10} (BARI Begun-8), V_5 (BARI Begun-1), V_6 (BARI Begun-4), V_1 (BARI Bt Begun-1) and V_4 (BARI Bt Begun-4) which contributed 24.34, 22.63, 14.75, 14.54, 14.43 and 13.82 cm fruit length, respectively. The lowest single fruit length was reported 9.54 cm by V_7 (BARI Begun-5) which was significantly different from all other varieties followed by V_8 (BARI Begun-6), V_{13} (BARI Hybrid Begun-4), V_3 (BARI Bt Begun-3), V_{11} (BARI Begun-9) and V_2 (BARI Bt Begun-2) that contributed 10.54, 11.54, 12.45, 12.52 and 13.65 cm fruit length, respectively. As a result, in case of fruit length (cm), it was found the following trend: V_{12} (BARI Begun-10 (Bholanath)) > V_9 (BARI Begun-7 (Singnath)) > V_{10} (BARI Begun-8) > V_5 (BARI Begun-1 (Uttara)) > V_6 (BARI Begun-4 (Kajla)) > V_1 (BARI Bt Begun-1) > V_4 (BARI Bt Begun-4) > V_2 (BARI Bt Begun-2) > V_{11} (BARI Begun-9 (Dohazari)) > V_3 (BARI Bt Begun-3) > V_{13} (BARI Hybrid Begun-4) > V_8 (BARI Begun-6 (Ishurdi local)) > V_7 (BARI Begun-5 (Nayantara)).

Fruit girth

The result obtained from Table 4.2.6 showed that different varieties had influence on fruit girth. The highest fruit girth has been reported (28.25 cm) in case of V_7 (BARI Begun-5) which was significantly different from others and followed by V_8 (BARI Begun-6), V_4 (BARI Bt Begun-4), V_{11} (BARI Begun-9), V_3 (BARI Bt Begun-3), V_{13} (BARI Hybrid Begun-4), V_5 (BARI Begun-1) and V_2 (BARI Bt Begun-2) that contributed 27.53, 25.54, 25.33, 24.34, 21.24, 16.54 and 15.53 cm, respectively. The lowest single fruit girth was reported 7.54 cm by V_9 (BARI Begun-7) which was significantly different from all other varieties followed by V_{10} (BARI Begun-8), V_6 (BARI Begun-4), V_{12} (BARI Begun-10) and V_1 (BARI Bt Begun-1) that contributed 9.52, 10.52, 12.55 and 13.15 cm, respectively. So, in case of single fruit girth (cm), it was found the following trend: V_7 (BARI Begun-5 (Nayantara)) > V_8 (BARI Begun-6 (Ishurdi local)) > V_4 (BARI Bt Begun-4) > V_{11} (BARI Begun-9 (Dohazari)) > V_3 (BARI

Bt Begun-3) > V_{13} (BARI Hybrid Begun-4) > V_5 (BARI Begun-1 (Uttara)) > V_2 (BARI Bt Bregun-2) > V_1 (BARI Bt Begun-1) >V_{12} (BARI Begun-10 (Bholanath)) > V_6 (BARI Begun-4 (Kajla)) > V_{10} (BARI Begun-8) > V_9 (BARI Begun-7 (Singnath)).

Single fruit weight

In case of single fruit weight, the highest result observed 322.81 g by V_{13} (BARI Hybrid Begun-4) which is significantly different from all other varieties followed by V_7 (BARI Begun-5), V_3 (BARI Bt Begun-3), V_8 (BARI Begun-6), V_4 (BARI Bt Begun-4), V_1 (BARI Bt Begun-1) and V_5 (BARI Begun-1) that contributed 321.63, 227.33, 206.76, 183.62, 180.83 and 179.03 g single fruit weight, respectively. On the other hand, the lowest single fruit weight observed (35.69 g) in V_{12} (BARI Begun-10) which is significantly different from all other brinjal varieties followed by V_{11} (BARI Begun-9), V_6 (BARI Begun-4), V_2 (BARI Bt Begun-2), V_{10} (BARI Begun-8) and V_9 (BARI Begun-7) which contributed 78.89, 103.92, 105.71, 109.96 and 165.21g single fruit weight, respectively. So, in case of single fruit weight (g), it was found the following trend V_3 (BARI Bt Begun-3) > V_7 (BARI Begun-5 (Nayantara)) > V_{13} (BARI Hybrid Begun-4) > V_8 (BARI Begun-6 (Ishurdi local)) > V_4 (BARI Bt Begun-4) > V_1 (BARI Bt Begun-1) > V_5 (BARI Begun-1 (Uttara)) > V_9 (BARI Begun-7 (Singnath)) > V_{10} (BARI Begun-8) > V_2 (BARI Bt Begun-2) > V_6 (BARI Begun-4 (Kajla)) > V_{11} (BARI Begun-9 (Dohazari)) > V_{12} (BARI Begun-10 (Bholanath)).

Table 4.2.6. Fruit related yield attributes in different brinjal varieties

Treatment	Fruit related yield attributes			
	No. of fruits/plant	Single fruit length (cm)	Fruit girth (cm)	Single fruit weight (g)
V_1	45.67 b	14.43 f	13.15 i	180.83 f
V_2	66.33 a	13.65 h	15.53 h	105.71 j
V_3	24.33 e	12.45 j	24.34 e	227.33 c
V_4	22.33 f	13.82 g	25.54 c	183.62 e
V_5	26.33 d	14.75 d	16.54 g	179.03 g
V_6	5.33 h	14.54 e	10.52 k	103.92 k
V_7	27.67 d	9.54 m	28.25 a	321.63 b
V_8	5.33 h	10.54 l	27.53 b	206.76 d
V_9	6.67 h	24.34 b	7.54 m	165.21 h
V_{10}	22.33 f	22.63 c	9.52 l	109.96 i
V_{11}	6.33 h	12.52 i	25.33 d	78.89 l
V_{12}	17.67 g	25.34 a	12.55 j	35.69 m
V_{13}	38.33 c	11.54 k	21.24 f	322.81 a
CV (%)	3.73	0.11	0.08	0.07
$LSD_{0.05}$	1.52	0.05	0.05	0.19

[In columns, each mean is the average of three replicates and the same letter with means indicate the statistically similar with each other at 5% level of significance with DMRT.

Here, V_1= BARI Bt Begun-1, V_2= BARI Bt Begun-2, V_3= BARI Bt Begun-3, V_4= BARI Bt Begun-4, V_5= BARI Begun-1 (Uttara), V_6= BARI Begun-4 (Kajla), V_7= BARI Begun-5 (Nayantara), V_8= BARI Begun-6 (Ishurdi local), V_9= BARI Begun-7 (Singnath), V_{10}= BARI Begun-8, V_{11}= BARI Begun-9 (Dohazari), V_{12}= BARI Begun-10 (Bholanath), V_{13}= BARI Hybrid Begun-4]

4.2.5. Yield

Significant variations were observed among the varieties in terms of fruit yield of brinjal. In case of fruit yield (kg/plot), the highest yield (8.90 kg) was recorded in V_{13} (BARI Hybrid Begun-4), which was statistically similar with V_5 (BARI Begun-1) and followed by V_1 (BARI Bt Brinjal-1), V_3 (BARI Bt Brinjal-3), V_2 (BARI Bt Brinjal-2), V_7 (BARI Begun-5), V_4 (BARI Bt Brinjal-4) and V_{10} (BARI Begun-8) that contributed 8.71, 8.26, 7.85, 7.01, 4.71, 4.10 and 2.45 kg yield per plot, respectively. On the other hand, the lowest yield (0.50 kg) was recorded in V_{11} (BARI Begun-8) which was statistically similar with V_6 (BARI Begun-4), V_{12} (BARI Begun-10), V_8 (BARI Begun-6) and V_9 (BARI Begun-7) that contributed 0.55, 0.63, 1.10 and 1.10 kg yield per plot, respectively.

More or less similar trend was observed in case of yield of fruits in ton per hectare where the highest yield was recorded in V_{13} (14.83 ton/ha) and lowest yield was recorded in V_{11} (0.83 ton/ha). As a result, the order of results in terms of increasing the yield of brinjal is V_{13} (BARI Hybrid Begun-4) > V_5 (BARI Begun-1 (Uttara)) > V_1 (BARI Bt Brinjal-1) > V_3 (BARI Bt Brinjal-3) > V_2 (BARI Bt Brinjal-2) > V_7 (BARI Begun-5 (Nayantara)) > V_4 (BARI Bt Brinjal-4) > V_{10} (BARI Begun-8) > V_8 (BARI Begun-6 (Ishurdi local)) > V_9 (BARI Begun-7 (Singnath)) > V_{12} (BARI Begun-10 (Bholanath)) > V_6 (BARI Begun-4 (Kajla)) > V_{11} (BARI Begun-9 (Dohazari)). Similar results were also reported by several researchers. Islam (2014) found that BARI Begun 5 provided the heighest yield.

Table 4.2.7. Fruit yield in different varieties of brinjal

Treatment	Fruit yield	
	Yield (kg/plot)	Yield (ton/ha)
V_1	8.26 b	12.89 b
V_2	7.01 d	10.33 d
V_3	7.85 c	11.67 c
V_4	4.10 f	8.67 f
V_5	8.71 a	13.76 a
V_6	0.55 i	0.89 i
V_7	4.71 e	9.83 e
V_8	1.10 h	6.93 h
V_9	1.10 h	6.89 h
V_{10}	2.45 g	7.31 g
V_{11}	0.50 i	0.83 i
V_{12}	0.63 i	0.93 i
V_{13}	8.90 a	14.83 a
CV (%)	3.37	3.37
$LSD_{0.05}$	0.24	0.24

[In columns, each mean is the average of three replicates and the same letter with means indicate the statistically similar with each other at 5% level of significance with DMRT.

Here, V_1= BARI Bt Begun-1, V_2= BARI Bt Begun-2, V_3= BARI Bt Begun-3, V_4= BARI Bt Begun-4, V_5= BARI Begun-1 (Uttara), V_6= BARI Begun-4 (Kajla), V_7= BARI Begun-5 (Nayantara), V_8= BARI Begun-6 (Ishurdi local), V_9= BARI Begun-7 (Singnath), V_{10}= BARI Begun-8, V_{11}= BARI Begun-9 (Dohazari), V_{12}= BARI Begun-10 (Bholanath), V_{13}= BARI Hybrid Begun-4]

4.2.6. Evaluation of factors affecting varietal preference

The factors affecting the varietal preference of brinjal were evaluated against brinjal shoot and fruit borer. Considering the purpose, the moisture content of leaves, trichome hair density on leaves, thorn density on leaves and stems were observed and recorded. The significant variations were observed among different brinjal varieties in terms of the above-mentioned factors of the eggplants (Table 4.2.8; 4.2.9 and 4.2.10).

(a) Moisture content of leaves

The significant variations were observed among different brinjal varieties in terms of moisture content of leaves at vegetative, early fruiting and late fruiting stages of brinjal in the field against brinjal shoot and fruit borer (Table 4.2.8). In case of vegetative stage of brinjal, the highest moisture content of leaves (87.56%) was recorded in V_{13} (BARI Hybrid Begun 4), which was statistically different from other varieties and followed by V_{10} (BARI Begun-8), V_6 (BARI Begun-4), V_2 (BARI Bt Begun-2), V_{11} (BARI Begun-9), V_{12} (BARI Begun-10), V_5 (BARI Begun-1) and V_1 (BARI Bt Begun-1) those contributed 87.13, 87.05, 86.88, 86.57, 86.19, 85.87 and 85.83% moisture, respectively. On the other hand, the lowest moisture content of leaves (83.67%) was recorded in V_5 (BARI Begun-1), which was statistically different from other varieties and followed by V_8 (BARI Begun-6), V_7 (BARI Begun-5), V_3 (BARI Bt Begun-3) and V_9 (BARI Begun-7) those manifested 83.88, 84.93, 84.89 and 85.33% moisture, respectively. More or less similar trends of results were recorded in terms of percent moisture content of leaves at early, and late fruiting stages of brinjal. As a result, the trends of moisture content for all varieties of brinjal is early fruiting stage > vegetative stage > late fruiting stage.

Considering the mean percent moisture content of leaves, the highest percent moisture content of leaves (88.20%) was recorded in V_{13} (BARI Hybrid Begun 4), which was statistically different from other varieties and followed by V_{10} (BARI Begun-8), V_6 (BARI Begun-4), V_{11} (BARI Begun-9), V_2 (BARI Bt Begun-2), V_{12} (BARI Begun-10), V_4 (BARI Bt Begun-4) and V_1 (BARI Bt Begun-1) those contributed 87.47, 87.19, 86.94, 86.87, 86.73 and 86.17% moisture, respectively. On the other hand, the lowest moisture content (83.53%) was recorded in V_5 (BARI Begun-1), which was statistically different from other varieties and followed by V_8 (BARI Begun-6), V_3 (BARI Bt

Begun-3), V_7 (BARI Begun-5) and V_9 (BARI Begun-7) those manifested 83.65, 85.22, 85.25 and 85.82% moisture, respectively.

Considering the comparison among the growth ages the brinjal, the moisture content of leaves was increased at early fruiting stage from that of vegetative stage of brinjal, but drastically decreased at older stage (late fruiting stage) of the brinjal.

Table 4.2.8. Moisture contents of leaves during different growing stage of plants in different varieties

Treatment	Leaf moisture content (%)			
	Vegetative stage	Early fruiting stage	Late fruiting stage	Mean
V_1	85.83 g	96.67 d	75.77 h	86.09 h
V_2	86.88 d	95.17 j	78.56 d	86.87 e
V_3	84.89 i	96.13 g	74.63 j	85.22 j
V_4	85.87 g	96.77 c	75.88 g	86.17 g
V_5	83.67 k	94.07 l	72.85 k	83.53 l
V_6	87.05 c	95.56 i	78.97 c	87.19 c
V_7	84.93 i	96.17 g	74.66 j	85.25 j
V_8	83.88 j	94.19 k	72.88 k	83.65 k
V_9	85.33 h	96.34 f	75.57 i	85.75 i
V_{10}	87.13 b	95.96 h	79.33 b	87.47 b
V_{11}	86.57 e	96.57 e	77.68 e	86.94 d
V_{12}	86.19 f	97.13 b	76.87 f	86.73 f
V_{13}	87.56 a	97.58 a	79.46 a	88.20 a
CV (%)	0.05	0.05	0.05	0.05
LSD $_{(0.05)}$	0.08	0.08	0.05	0.08

[In columns, each mean is the average of three replicates and the same letter with means indicate the statistically similar with each other at 5% level of significance with DMRT.

Here, V_1= BARI Bt Begun-1, V_2= BARI Bt Begun-2, V_3= BARI Bt Begun-3, V_4= BARI Bt Begun-4, V_5= BARI Begun-1 (Uttara), V_6= BARI Begun-4 (Kajla), V_7= BARI Begun-5 (Nayantara), V_8= BARI Begun-6 (Ishurdi local), V_9= BARI Begun-7 (Singnath), V_{10}= BARI Begun-8, V_{11}= BARI Begun-9 (Dohazari), V_{12}= BARI Begun-10 (Bholanath), V_{13}= BARI Hybrid Begun-4]

From the above findings it was revealed that V_{13} (BARI Hybrid Begun 4) performed as the most suitable brinjal varieties in terms of percent moisture content of leaves (88.20%), whereas the V_5 (BARI Begun-1) performed as the least suitable varieties in terms of moisture percent (83.53%) of leaves. As a result, the of least preferable brinjal varieties in terms of percent moisture content is V_{13} (BARI Hybrid Begun-4) > V_{10} (BARI Begun-8) > V_6 (BARI Begun-4 (Kajla)) > V_{11} (BARI Begun-9 (Dohazari)) > V_2 (BARI Bt Brinjal-2) > V_{12} (BARI Begun-10 (Bholanath)) > V_4 (BARI Bt Begun-4) > V_1 (BARI Bt Begun-1) > V_9 (BARI Begun-7 (Singnath)) > V_7 (BARI Begun-5 (Nayantara)) > V_3 (BARI Bt Begun-3) > V_8 (BARI Begun-6 (Ishurdi local)) > V_5 (BARI Begun-1 (Uttara)). Similar results were also reported by several researchers. Islam (2014) found that BARI Begun 7 performed as the most suitable brinjal varieties in terms of percent moisture content of leaves.

(b) Trichome hair density

The significant variations were observed among different brinjal varieties in terms of Trichome hair density of leaves per cm^2 at fully opened top first, third, fifth and seventh leaf of brinjal in the field (Table 4.2.9). In terms of top first leaf, the highest trichome hair per cm^2 has been recorded (23.88 trichome/cm^2) in V_5 (BARI Begun 1) which is significantly different from all other varieties followed by V_4 (BARI Bt Begun-4), V_7 (BARI Begun-5), V_3 (BARI Bt Begun-3), V_9 (BARI Begun-7), V_8 (BARI Begun-6), V_1 (BARI Bt Begun-1) and V_{12} (BARI Begun-10) and those contributed 23.79, 23.19, 22.63, 22.57, 21.79, 21.23 and 13.88 trichome/cm^2, respectively. On the other hand, the lowest number of trichome per cm^2 on top first leaf was observed (8.66 trichome/cm^2) in V_{13} (BARI Hybrid Begun 4) was statistically different from other varieties and followed by V_{10} (BARI Begun-8), V_6 (BARI Begun-4), V_2 (BARI Bt Begun-2) and V_{11} (BARI Begun 9) and those contributed 9.97, 11.37, 12.47 and 13.47 trichome/cm^2, respectively. More or less similar results were recorded in terms of number of trichome hair density per cm^2 at top third leaf, top fifth leaf and top seventh leaf where the highest number of trichome hair density per cm^2 was recorded in terms of V_5 (BARI Begun 1) and lowest number of trichome hair density per cm^2 was recorded in terms of V_{13} (BARI Hybrid Begun 4). Trichome hair density gradually decreased with the age and lower position of leaves. Thus, less trichome hair density was observed in top seventh leaves of plant. As a result, the order of trends of number of trichome per cm^2 for all varieties of brinjal was top third leaf > top first leaf > top fifth leaf> Top seventh leaf.

Considering the mean number of trichome hair density per cm^2, the highest number of trichome per cm^2 (24.00 trichome/cm^2) was observed in V_5 (BARI Begun 1) which is significantly different from all other varieties followed by V_4 (BARI Bt Begun-4), V_7 (BARI Begun-5), V_3 (BARI Bt Begun-3), V_9 (BARI Begun-7), V_8 (BARI Begun-6), V_1 (BARI Bt Begun-1) and V_{12} (BARI Begun-10), those contributed 23.78, 20.32, 19.91, 18.73, 15.76, 14.63 and 12.26 trichome/cm^2, respectively. On the other hand, the lowest number of trichome per cm^2 on leaf was observed (8.26 trichome/cm^2) in V_{13} (BARI Hybrid Begun 4) was statistically different from other varieties and followed by V_{10} (BARI Begun-8), V_6 (BARI Begun-4), V_2 (BARI Bt Begun-2) and V_{11} (BARI Begun 9) and those contributed 9.17, 10.92, 11.31 and 18.73 trichome/cm^2, respectively.

From the above findings it was revealed that V_8 (BARI Begun-6) performed as the best suitable brinjal varieties in terms of trichome hair density per cm^2 (24.00 trichome/cm^2), whereas the V_9 (BARI Begun-7) performed as the least suitable varieties in terms of trichome hair density per cm^2 (8.26 trichome/cm^2). As a result, the order of trends of the most preferable brinjal varieties in terms of trichome hair density per cm^2 is V_8 (BARI Begun-6 (Ishurdi local)) > V_4 (BARI Bt Begun-4) > V_7 (BARI Begun-5 (Nayantara)) > V_3 (BARI Bt Begun-3) > V_{13} (BARI Hybrid Begun-4) > V_5 (BARI Begun-1 (Uttara)) > V_1 (BARI Bt Begun-1) > V_{12} (BARI Begun-10 (Bholanath)) > V_{11} (BARI Begun-9 (Dohazari)) > V_2 (BARI Bt Begun-2) > V_6 (BARI Begun-4 (Kajla)) > V_{10} (BARI Begun-8) > V_9 (BARI Begun-7 (Singnath)). About similar results were also reported by several researchers. Islam (2014) found that BARI Begun 6 performed as the most suitable brinjal varieties in terms of trichome hair density per cm^2.

Table 4.2.9. Leaf Trichome density at various canopy strata of plants in different varieties

Treatment	Trichome hair density (no./cm^2)				
	Top first leaf	Top third leaf	Top fifth leaf	Top seventh leaf	Mean
V_1	21.23 g	13.94 g	11.76 g	11.57 g	14.63 g
V_2	12.47 j	12.79 j	10.56 j	9.43 j	11.31 j
V_3	22.63 d	22.67 d	20.21 d	14.13 d	19.91 d
V_4	23.79 b	27.19 b	24.47 b	19.67 b	23.78 b
V_5	23.88 a	27.47 a	24.76 a	19.88 a	24.00 a
V_6	11.37 k	12.48 k	10.19 k	9.65 i	10.92 k
V_7	23.19 c	22.88 c	20.57 c	14.65 c	20.32 c
V_8	21.79 f	14.13 f	14.21 f	12.92 f	15.76 f
V_9	22.57 e	19.67 e	19.33 e	13.33 e	18.73 e
V_{10}	9.97 l	11.13 l	8.47 l	7.11 l	9.17 l
V_{11}	13.47 i	12.96 i	10.87 i	9.07 k	11.59 i
V_{12}	13.88 h	13.03 h	11.43 h	10.69 h	12.26 h
V_{13}	8.66 m	9.78 m	7.89 m	6.71 m	8.26 m
CV (%)	0.10	0.09	0.11	0.11	0.11
LSD $_{(0.05)}$	0.05	0.05	0.05	0.05	0.05

[In columns, each mean is the average of three replicates and the same letter with means indicate the statistically similar with each other at 5% level of significance with DMRT.

Here, V_1= BARI Bt Begun-1, V_2= BARI Bt Begun-2, V_3= BARI Bt Begun-3, V_4= BARI Bt Begun-4, V_5= BARI Begun-1 (Uttara), V_6= BARI Begun-4 (Kajla), V_7= BARI Begun-5 (Nayantara), V_8= BARI Begun-6 (Ishurdi local), V_9= BARI Begun-7 (Singnath), V_{10}= BARI Begun-8, V_{11}= BARI Begun-9 (Dohazari), V_{12}= BARI Begun-10 (Bholanath), V_{13}= BARI Hybrid Begun-4]

(c) Thorn density

Significant variation was found in terms of thorn density number per top fully open first leaf. The highest number of thorn density per top fully open first leaf was recorded 4.33 in V_5 (BARI Begun 1) which is significantly different from all other brinjal varieties followed by V_4 (BARI Bt Brinjal-4), V_7 (BARI Begun-5), V_3 (BARI Bt Brinjal-3), V_9 (BARI Begun-7), V_8 (BARI Begun-6), V_1 (BARI Bt Brinjal-1) and V_{12} (BARI Begun-10) those contributed 4.21, 1.03, 0.98, 0.89, 0.88, 0.72 and 0.67 thorn, respectively. On the other hand, least number of thorns per top fully opened leaf was recorded (0.13) in V_{13} (BARI Hybrid Begun 4) which was statistically different from other varieties and followed by V_{10} (BARI Begun 8), V_6 (BARI Begun-4), V_2 (BARI Bt Brinjal-2) and V_{11} (BARI Begun 9) othose contributed 0.19, 0.22, 0.27 and 0.36 thorn, respectively.

More or less similar trend was found in case of thorn density number per 10cm of apical stem of brinjal plant. The highest number of thorn density per 10 cm of apical stem was recorded (6.47) in V_5 (BARI Begun 1) which was significantly different from all other varieties. On the other hand the least number of thorns per 10 cm of apical stem was recorded (1.56) in terms of V_{13} (BARI Hybrid Begun-4) which was statistically similar to V_3 (BARI Bt Brinjal-3) that manifested 2.41.

From the above findings, it was revealed that, V_5 (BARI Begun 1) possessed the highest number of thorn density per top fully open first leaf and per 10 cm of apical stem (4.33 and 6.47) respectively while the least amount of thorn density per top fully open first leaf and per 10 cm of apical stem was recorded in terms of V_{13} (BARI Hybrid Begun 4) (0.13 and 1.56, respectively). Similar results were also reported by several researchers. Islam (2014) found that BARI Begun 6 performed as the highest number of thorn density per top fully open first leaf and per 10 cm of apical stem.

Table 4.2.10. Leaf and stem thorns in different brinjal varieties

Treatment	Thorn density (No./leaf or stem)	
	Top first leaf	Stem (10 cm apical part)
V_1	0.72 e	5.03 d
V_2	0.27 g	2.87 g
V_3	0.98 c	2.41 j
V_4	4.21 b	6.21 b
V_5	4.33 a	6.47 a
V_6	0.22 gh	2.80 h
V_7	1.03 c	2.57 i
V_8	0.88 d	5.09 c
V_9	0.89 d	2.90 g
V_{10}	0.19 h	3.36 f
V_{11}	0.36 f	4.09 e
V_{12}	0.67 e	6.19 b
V_{13}	0.13 i	1.56 j
CV (%)	0.33	0.92
$LSD_{0.05}$	0.05	0.05

[In columns, each mean is the average of three replicates and the same letter with means indicate the statistically similar with each other at 5% level of significance with DMRT.

Here, V_1= BARI Bt Begun-1, V_2= BARI Bt Begun-2, V_3= BARI Bt Begun-3, V_4= BARI Bt Begun-4, V_5= BARI Begun-1 (Uttara), V_6= BARI Begun-4 (Kajla), V_7= BARI Begun-5 (Nayantara), V_8= BARI Begun-6 (Ishurdi local), V_9= BARI Begun-7 (Singnath), V_{10}= BARI Begun-8, V_{11}= BARI Begun-9 (Dohazari), V_{12}= BARI Begun-10 (Bholanath), V_{13}= BARI Hybrid Begun-4]

4.2.7. Relationship between shoot and fruit infestation and moisture percentage of leaf

4.2.7.1. Fruit infestation by number

Correlation study was done to establish the relationship between the percent fruit infestation (number) and moisture percentage of leaf (%) of brinjal among different varieties of brinjal. From the study it was revealed that, significant correlation was observed between the fruit infestation by number and moisture percentage of leaf of brinjal (Figure 4.2.1). It was evident from the Figure 4.2.1 that the regression equation y = 0.023x + 85.629 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.0352) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a positive relationship between fruit infestation (number) and moisture of leaf of brinjal, i.e., the infestation of fruit (number) by brinjal shoot and fruit borer increased with the increase of the moisture percentage of leaf.

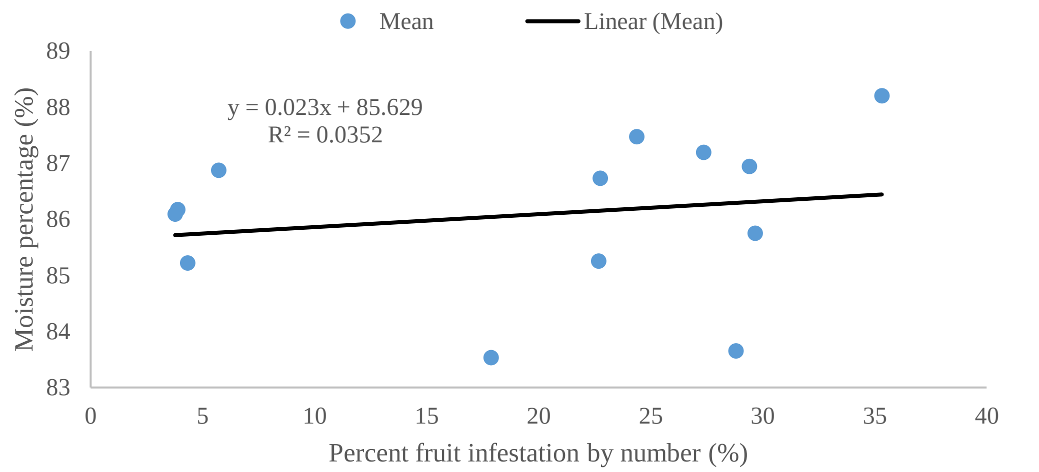


Figure 4.2.1. Relationship between moisture percentage of leaf and percent fruit infestation by number of brinjal caused by BSFB

4.2.7.2. Fruit infestation by weight

Correlation study was done to establish the relationship between the percent fruit infestation (weight) and moisture percentage of leaf (%) of brinjal among different varieties of brinjal. From the study it was revealed that, significant correlation was observed between the fruit infestation by weight and moisture percentage of leaf of brinjal (Figure 4.2.2). It was evident from the Figure 4.2.2 that the regression equation y = 0.0299x + 85.393 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.0873) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a positive relationship between fruit infestation (weight) and moisture of leaf of brinjal, i.e., the infestation of fruit (weight) by brinjal shoot and fruit borer increased with the increase of the moisture percentage of leaf.

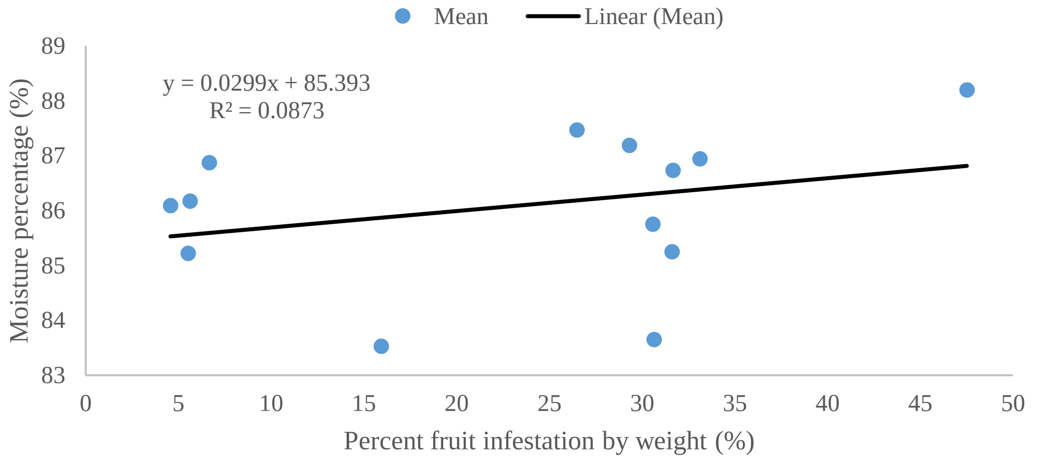


Figure 4.2.2. Relationship between moisture percentage of leaf and percent fruit infestation by weight of brinjal caused by BSFB

4.2.7.3. Shoot infestation

Correlation study was done to establish the relationship between the percent shoot infestation and moisture percentage of leaf (%) of brinjal among different varieties of brinjal. From the study it was revealed that, significant correlation was observed between the shoot infestation and moisture percentage of leaf of brinjal (Figure 4.2.3). It was evident from the Figure 4.2.3 that the regression equation y = 0.0084x + 85.931 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.0032) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a positive relationship between shoot infestation and moisture of leaf of brinjal, i.e., the infestation of shoot by brinjal shoot and fruit borer increased with the increase of the moisture percentage of leaf.

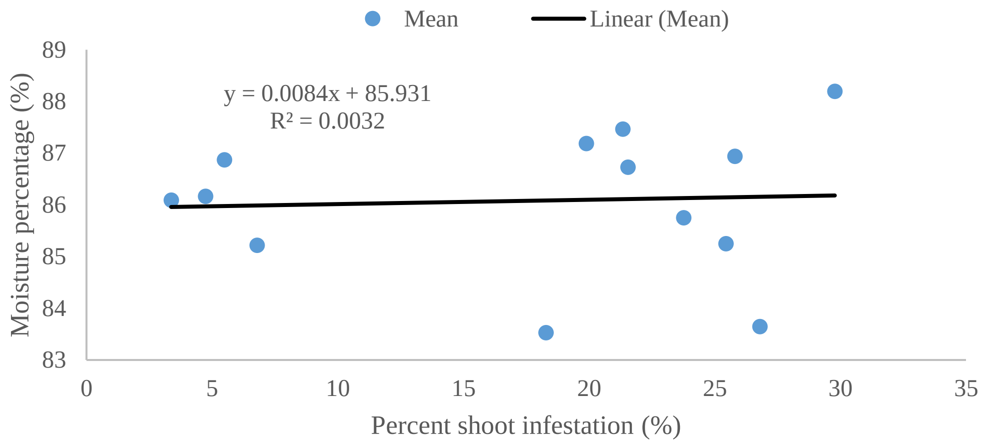


Figure 4.2.3. Relationship between moisture percentage of leaf and percent shoot infestation of brinjal caused by BSFB

4.2.8. Relationship between shoot and fruit infestation and trichome hair density of leaves per cm^2

4.2.8.1. Fruit infestation by number

Correlation study was done to establish the relationship between the percent fruit infestation (number) and trichome hair density of leaves per cm^2 of brinjal among different varieties of brinjal. From the study it was revealed that, significant correlation was observed between the fruit infestation by number and trichome hair density of leaves per cm^2 of brinjal (Figure 4.2.4). It was evident from the Figure 4.2.4 that the regression equation y = -0.2044x + 19.458 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.1852) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a negative relationship between fruit infestation (number) and trichome hair density of leaves per cm^2 of brinjal, i.e., the infestation of fruit (number) by brinjal shoot and fruit borer decreased with the increase of the trichome hair density of leaves per cm^2.

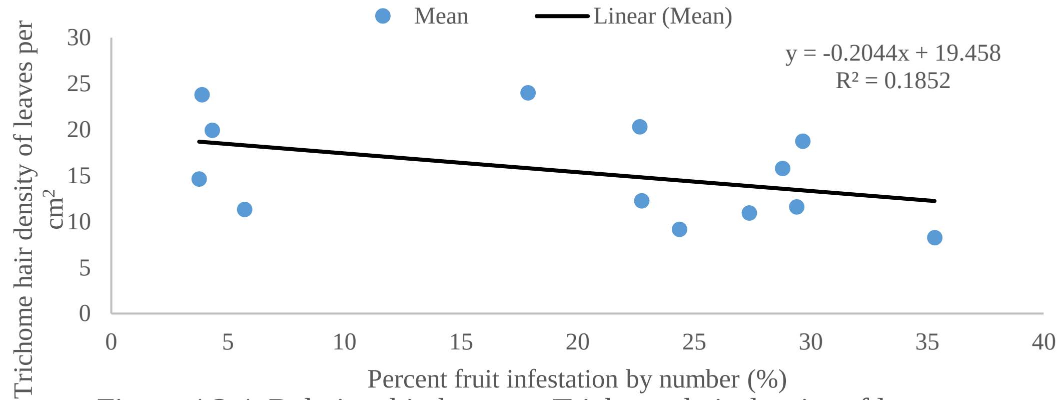


Figure 4.2.4. Relationship between Trichome hair density of leaves per cm^2 and percent fruit infestation by number of brinjal caused by BSFB

4.2.8.2. Fruit infestation by weight

Correlation study was done to establish the relationship between the percent fruit infestation (weight) and trichome hair density of leaves per cm^2 of brinjal among different varieties of brinjal. From the study it was revealed that, significant correlation was observed between the fruit infestation by weight and trichome hair density of leaves per cm^2 of brinjal (Figure 4.2.5). It was evident from the Figure 4.2.5 that the regression equation y = -0.1858x + 19.712 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.2244) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a negative relationship between fruit infestation (weight) and trichome hair density of leaves per cm^2, i.e., the infestation of fruit (weight) by brinjal shoot and fruit borer decreased with the increase of the trichome hair density of leaves per cm^2.

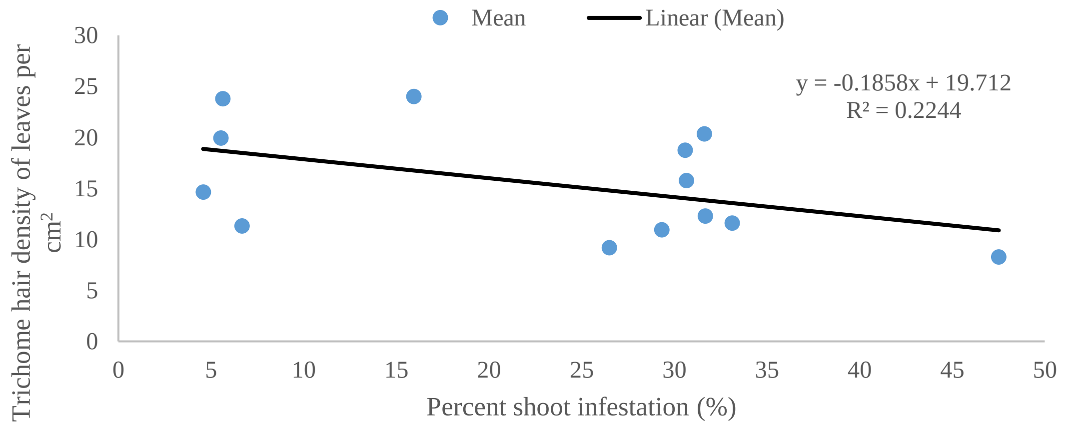


Figure 4.2.5. Relationship between Trichome hair density of leaves per cm^2 and percent shoot infestation of brinjal caused by BSFB

4.2.8.3. Shoot infestation

Correlation study was done to establish the relationship between the percent shoot infestation and trichome hair density of leaves per cm^2 of brinjal among different varieties of brinjal. From the study it was revealed that, significant correlation was observed between the shoot infestation and trichome hair density of leaves per cm^2 of brinjal (Figure 4.2.6). It was evident from the Figure 4.2.6 that the regression equation $y = -0.1803x + 18.666$ gave a good fit to the data, and the co-efficient of determination ($R^2 = 0.0985$) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a negative relationship between shoot infestation and trichome hair density of leaves per cm^2 of brinjal, i.e., the infestation of shoot by brinjal shoot and fruit borer decreased with the increase of the trichome hair density of leaves per cm^2.

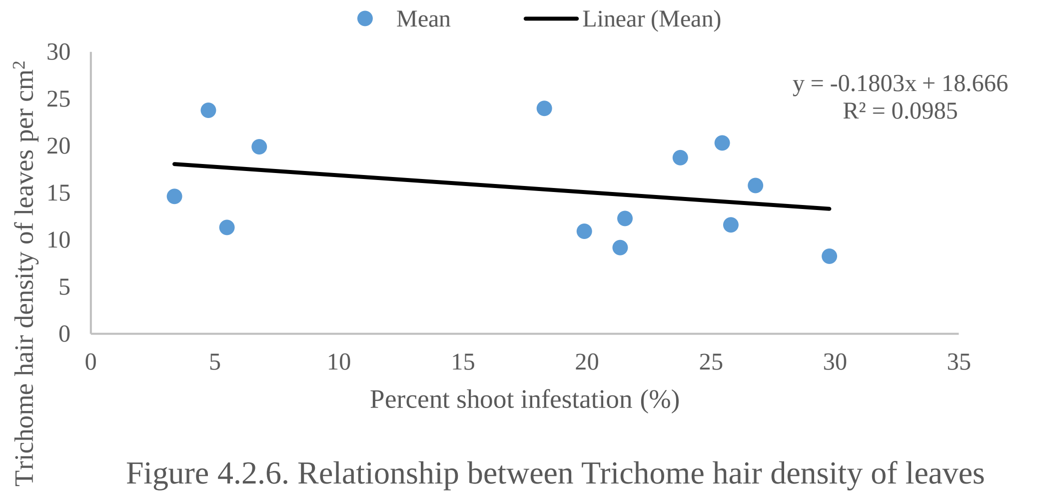


Figure 4.2.6. Relationship between Trichome hair density of leaves per cm^2 and percent shoot infestation of brinjal caused by BSFB

4.2.9. Relationship between shoot and fruit infestation and number of thorn per top first leaf

4.2.9.1. Fruit infestation by number

Correlation study was done to establish the relationship between the percent fruit infestation (number) and number of thorn per top first leaf of brinjal among different varieties of brinjal. From the study it was revealed that, significant correlation was observed between the fruit infestation by number and number of thorn per top first leaf of brinjal (Figure 4.2.7). It was evident from the Figure 4.2.7 that the regression equation y = -0.0478x + 2.0858 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.1465) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a negative relationship between fruit infestation (number) and number of thorn per top first leaf of brinjal, i.e., the infestation of fruit (number) by brinjal shoot and fruit borer decreased with the increase of the number of thorn per top first leaf.

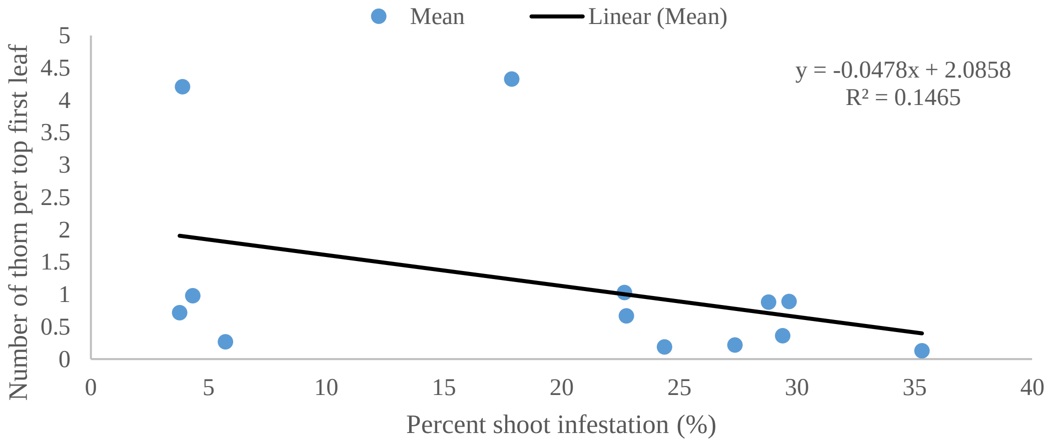


Figure 4.2.7. Relationship between thorn density of top first leaf and number of thorn per top first leaf of brinjal caused by BSFB

4.2.9.2. Fruit infestation by weight

Correlation study was done to establish the relationship between the percent fruit infestation (weight) and number of thorn per top first leaf of brinjal among different varieties of brinjal. From the study it was revealed that, significant correlation was observed between the fruit infestation by weight and number of thorn per top first leaf of brinjal (Figure 4.2.8). It was evident from the Figure 4.2.8 that the regression equation y = -0.0446x + 2.1704 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.1866) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a negative relationship between fruit infestation (weight) and number of thorn per top first leaf, i.e., the infestation of fruit (weight) by brinjal shoot and fruit borer decreased with the increase of the number of thorn per top first leaf.

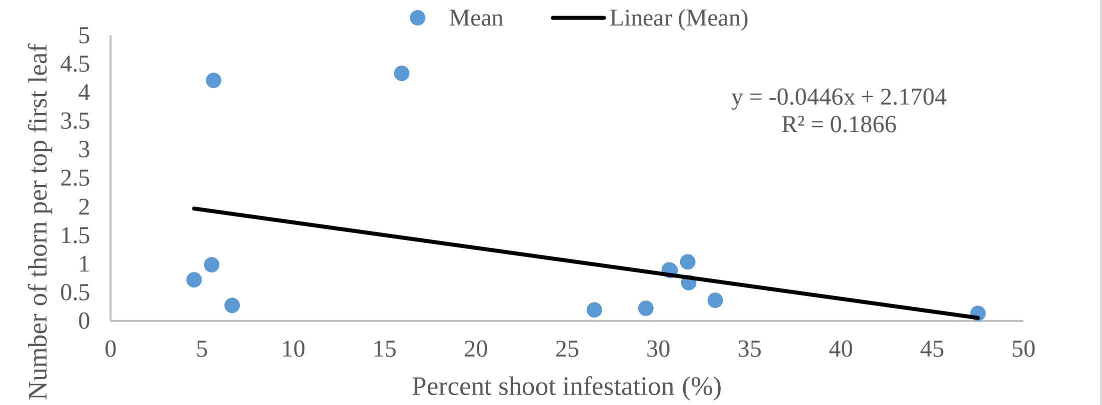


Figure 4.2.8. Relationship between thorn density of top first leaf and number of thorn per top first leaf of brinjal caused by BSFB

4.2.9.3. Shoot infestation

Correlation study was done to establish the relationship between the percent shoot infestation and number of thorn per top first leaf of brinjal among different varieties of brinjal. From the study it was revealed that, significant correlation was observed between the shoot infestation and number of thorn per top first leaf of brinjal (Figure 4.2.9). It was evident from the Figure 4.2.9 that the regression equation y = -0.047x + 1.9877 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.097) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a negative relationship between shoot infestation and number of thorn per top first leaf of brinjal, i.e., the infestation of shoot by brinjal shoot and fruit borer decreased with the increase of the number of thorn per top first leaf.

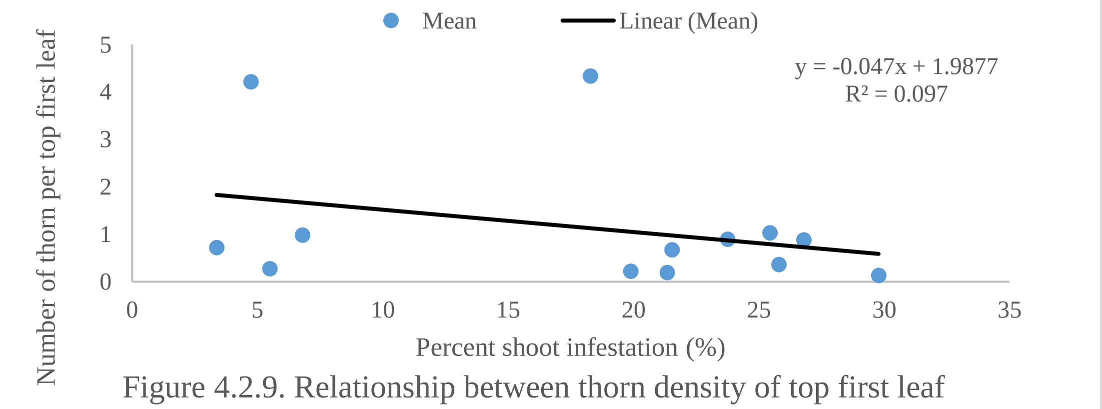


Figure 4.2.9. Relationship between thorn density of top first leaf and percent shoot infestation of brinjal caused by BSFB

4.2.10. Relationship between shoot and fruit infestation and number of thorn per 10cm apical part of stem

4.2.10.1. Fruit infestation by number

Correlation study was done to establish the relationship between the percent fruit infestation (number) and number of thorn per 10cm apical part of stem of brinjal among different varieties of brinjal. From the study it was revealed that, significant correlation was observed between the fruit infestation by number and number of thorn per 10cm apical part of stem of brinjal (Figure 4.2.10). It was evident from the Figure 4.2.10 that the regression equation $y = -0.0409x + 4.7697$ gave a good fit to the data, and the co-efficient of determination ($R^2 = 0.0791$) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a negative relationship between fruit infestation (number) and number of thorn per 10cm apical part of stem of brinjal, i.e., the infestation of fruit (number) by brinjal shoot and fruit borer decreased with the increase of the number of thorn per 10cm apical part of stem.

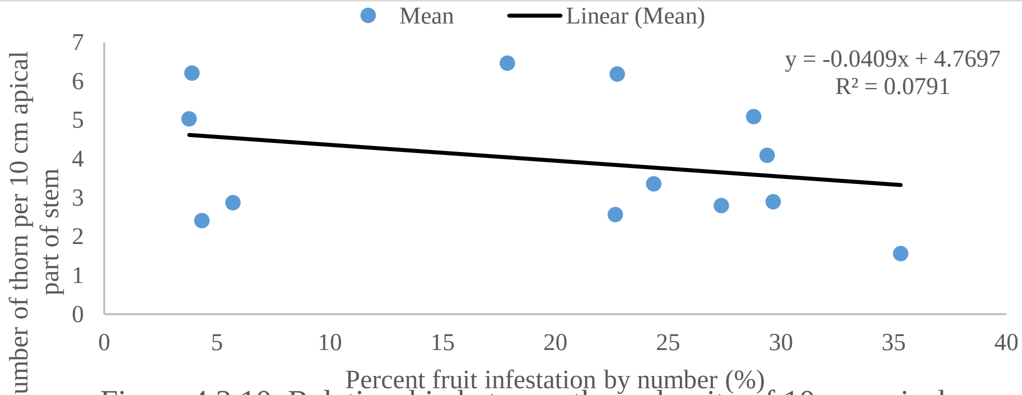


Figure 4.2.10. Relationship between thorn density of 10 cm apical part of stem and percent fruit infestation by number of brinjal caused by BSFB

4.2.10.2. Fruit infestation by weight

Correlation study was done to establish the relationship between the percent fruit infestation (weight) and number of thorn per 10cm apical part of stem of brinjal among different varieties of brinjal. From the study it was revealed that, significant correlation was observed between the fruit infestation by weight and number of thorn per 10cm apical part of stem of brinjal (Figure 4.2.11). It was evident from the Figure 4.2.11 that the regression equation $y = -0.0397x + 4.8788$ gave a good fit to the data, and the co-efficient of determination (R^2 = 0.1093) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a negative relationship between fruit infestation (weight) and number of thorn per 10cm apical part of stem, i.e., the infestation of fruit (weight) by brinjal shoot and fruit borer decreased with the increase of the number of thorn per 10cm apical part of stem.

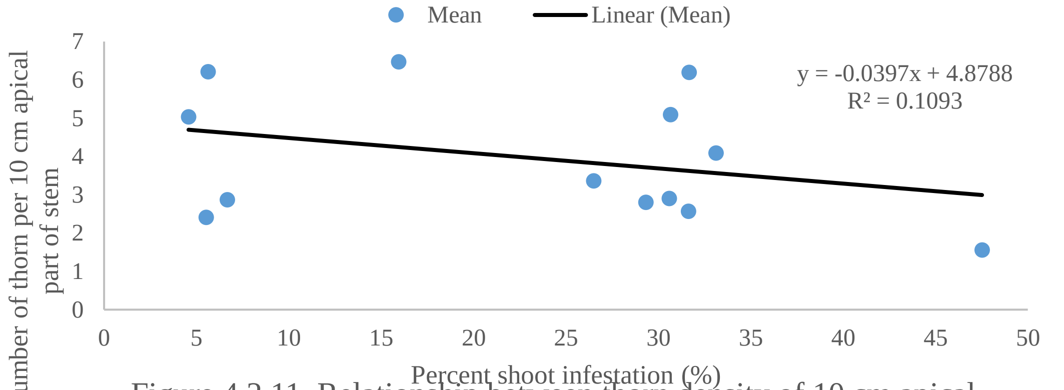


Figure 4.2.11. Relationship between thorn density of 10 cm apical part of stem and percent shoot infestation of brinjal caused by BSFB

4.2.10.3. Shoot infestation

Correlation study was done to establish the relationship between the percent shoot infestation and number of thorn per 10cm apical part of stem of brinjal among different varieties of brinjal. From the study it was revealed that, significant correlation was observed between the shoot infestation and number of thorn per 10cm apical part of stem (Figure 4.2.12). It was evident from the Figure 4.2.12 that the regression equation y = -0.0412x + 4.7034 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.0549) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a negative relationship between shoot infestation and number of thorn per 10cm apical part of stem of brinjal, i.e., the infestation of shoot by brinjal shoot and fruit borer decreased with the increase of the number of thorn per 10cm apical part of stem.

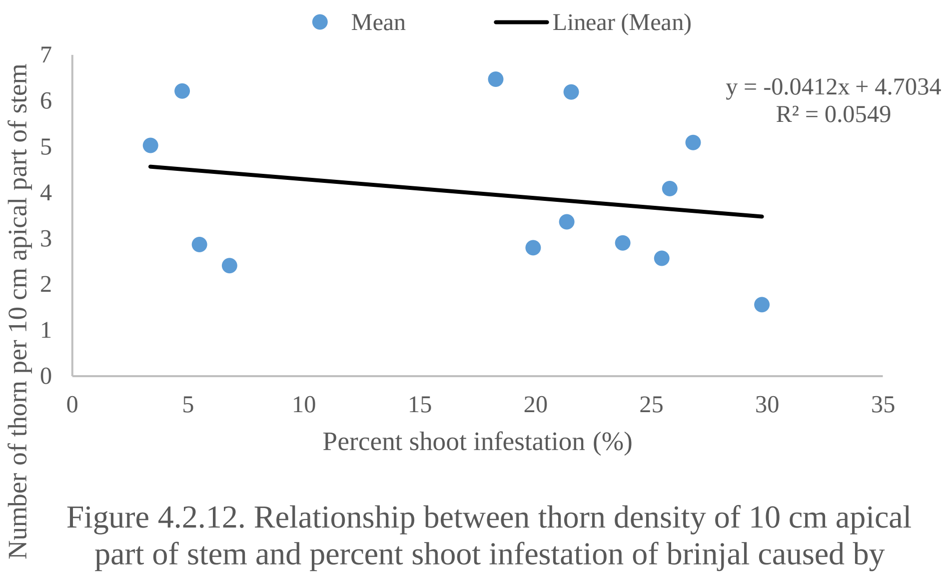


Figure 4.2.12. Relationship between thorn density of 10 cm apical part of stem and percent shoot infestation of brinjal caused by BSFB

Experiment-3: Efficiency of different pheromone traps and their setting positions for capturing adult moth of *Leucinodes orbonalis*

The present study was conducted to evaluate the efficiency of pheromone traps and traping methods for capturing adult moth of *Leucinodes orbonalis* in brinjal field under the Department of Entomology of Sher-e-Bangla Agricultural University, Dhaka during the period from October, 2017 to March, 2018. Findings of the study have been presented and discussed with interpretations in the following sub-headings:

4.3.1. Capturing capacity of pheromone traps

(a) Capturing efficiency of different types of pheromone traps: Significant variations among three types of pheromone traps were observed in terms of capturing capacity of adult BSFB moths. From the findings, it was revealed that the highest 3.78 adult moths per trap at three days interval was captured in the T_2 (BARI Trap II or Delta Trap), which was statistically different from other two trap types. This was followed by T_3 (Dry Pheromone Trap) that captured on an average 3.22 adult moths per trap at three days interval. While the lowest number (1.78 moth per trap/three days interval) of adult moths was captured in the T_1 (BARI Trap I or Traditional Trap) (Figure 4.3.1).

Results of the present study indicate that all the tested pheromone traps like BARI Trap-I, BARI Trap-II and Indian funnel trap (Dry pheromone Trap) had promising effects on the caught of male BSFB moths under natural field conditions. During the study, BARI Trap-II was found to be excellent in trapping the moths as compared to other two traps. The present finding is conformed with Andagopal *et al.* (2011) who reported that the Wota-T trap is the best one in capturing the male BSFB moths. Arvinda *et al.* (2017) concluded that the number of moths caught in water trap was found enormously significant at 1st week after installation. Our outcomes are also comparable with those of Aravinda *et al.* (2017). They opined that the water trap (WOTA) model had significantly highest number of moths catches (seasonal mean of 3.08 moths/trap/five days). The present findings are in accordance with Andagopal *et al*. (2011) and Rajneesh (2006). They cited that the water trap (Wota-T) was found as the best one which caught significantly a greater number of moths as compared to others.

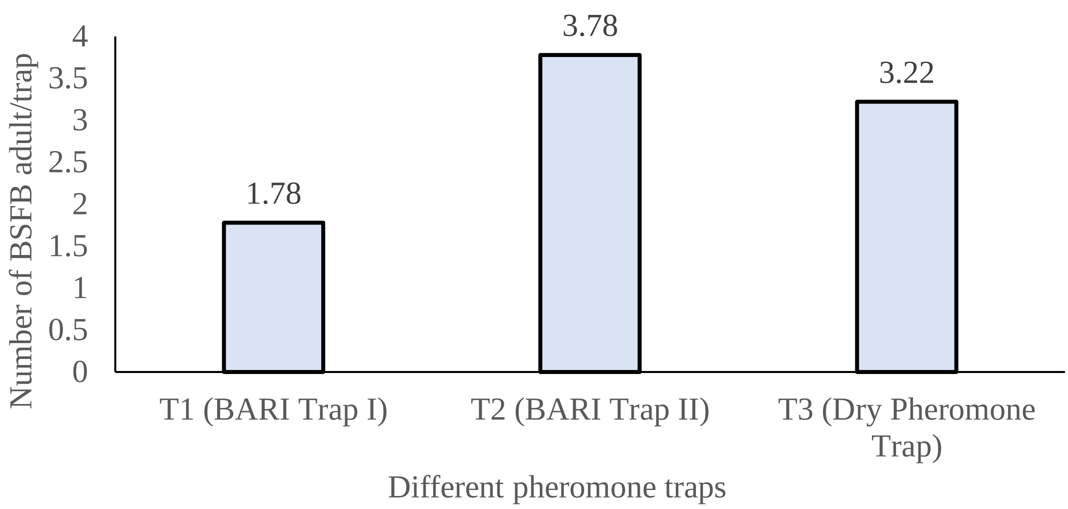


Figure 4.3.1: Efficiency of different types of pheromone traps in capturing adult BSFB moths ($LSD_{0.05}$ = 0.52)

(b) Capturing efficiency of setting position of pheromone traps: Significant variations among three setting positions of pheromone traps were observed in terms of capturing capacity of adult BSFB moths. From the findings, it was revealed that the highest 3.37 adult moths per trap at three days interval was captured in the L_2 setting position (Canopy level of trap), which was statistically similar with L_3 setting position (Lower canopy level) that captured 3.0 adult moths per trap at three days interval, but statistically different from L_1 setting position (Upper canopy level) that captured the lowest number of adult moths (2.11 per trap per plot) at three days interval (Figure 4.3.2).

From the above findin it was concluded that, the different positions of the trap setting performed differently regarding the catching or trapping of BSFB adults. Setting of pheromone trap at canopy level in the brinjal plants performed best in capturing adult moths than that of setting in lower canopy and upper canopy level of brinjal plants. Similar results were also experienced by Niranjana *et al.* (2017) and Rahman *et al.* (2009). They found that trap settled at crop canopy height level proved to be the most optimum in Wota-T (Water Trap) traps for capturing male moths. Our present findings are comparable with Sarker *et al.* (2022) and Uddin *et al.* (2008). They found that trap settled below crop canopy level caught more male moth of BSFB.

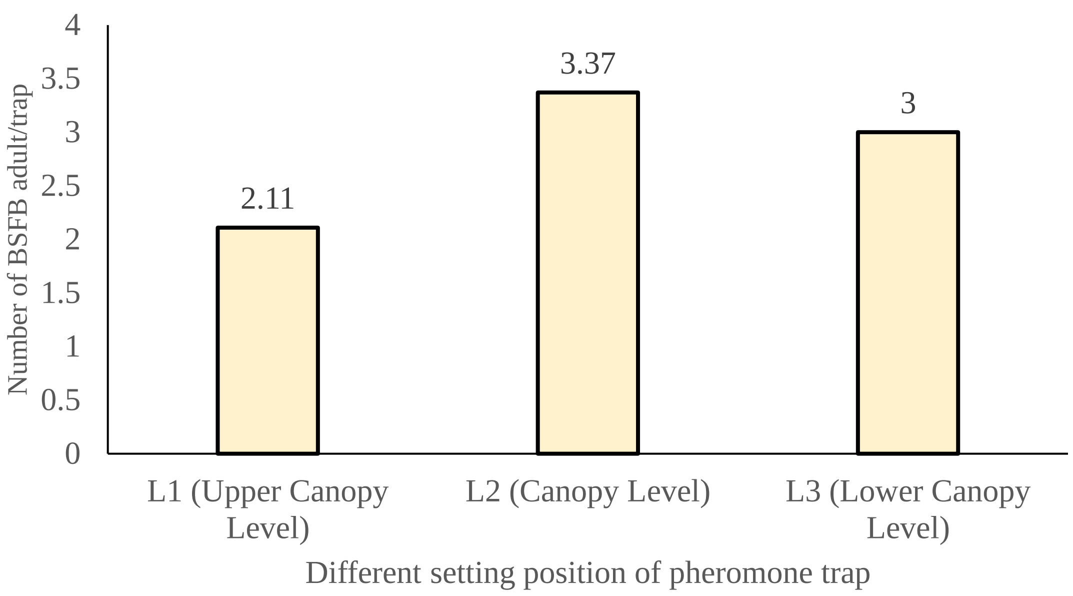


Figure 4.3.2: Effeciency of setting position of pheromone traps in capturing adult BSFB moths ($LSD_{0.05}$= 0.74)

(c) Interaction efficiency of types and setting position of pheromone traps

From the findings of combined effect of trap types and setting position, it was observed that, there was statistical variations among different types pheromone traps along with their setting position in terms of capturing number of adult BSFB moths per trap per plot. The average highest number (5.0) of adult BSFB moths per trap per plot was captured in T_2L_2 (i.e., BARI Trap II when set at the canopy level), which was statistically different from all other combination of trap types and setting positions, but followed by 3.67 adult BSFB moth per trap per plot captured in T_2L_3 ((i.e., BARI Trap II set at the lower canopy level) and T_3L_2 (i.e., Dry Trap when set at the canopy level) that was statistically similary with T_3L_3 (3.33 adult BSFB moths per trap per plot). These were followed by 2.67 adult BSFB moths captured in T_2L_1 (i.e., BARI Trap II when set at upper canopy level), T_1L_2 (i.e., BARI Trap I when set at canopy level) and T_3L_1 (i.e., Dry Trap when set at upper canopy level). On the other hand, the lowest average number (1.0) of adult BSFB moth per trap per plot was captured in T_1L_1 i.e., BARI Trap I when set at upper canopy level of brinjal field, which was statistically similar with T_1L_3 i.e., BARI Trap I when set at lower canopy level (Table-4.3.1).

From the above findings it was revealed that the BARI Trap II showed the best efficiency in capturing adult BSFB moths when set at canopy level in the brinjal field rather than other types of pheromone traps and any other setting position.

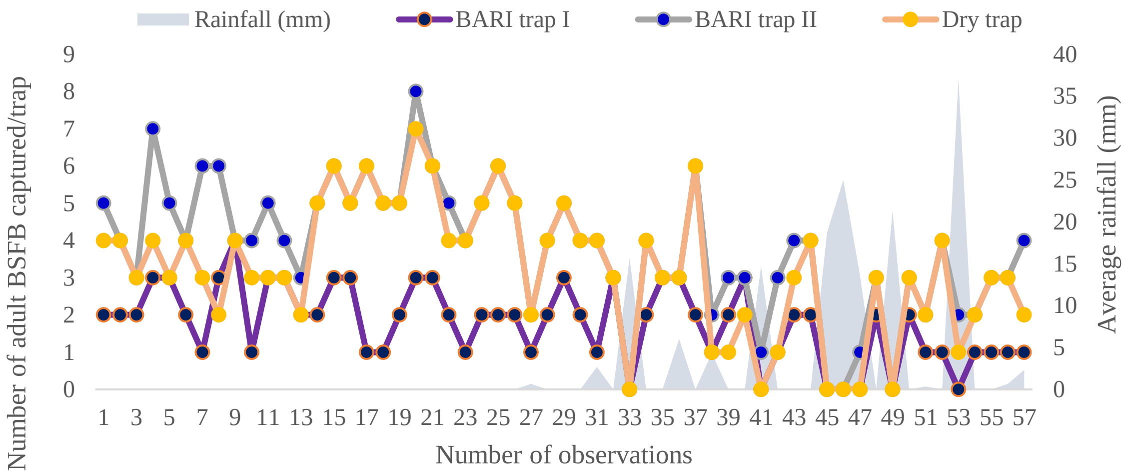
Table-4.3.1: Effect of different pheromone traps and different location on the number of BSFB per plot of brinjal

Type of traps	Setting position	No. of adult BSFB moth captured per trap
T_1 (BARI Trap I)	L_1 (Upper canopy)	1.00 d
	L_2 (Canopy level)	2.67 bc
	L_3 (Lower canopy)	1.67 cd
T_2 (BARI Trap II)	L_1 (Upper canopy)	2.67 bc
	L_2 (Canopy level)	5.00 a
	L_3 (Lower canopy)	3.67 b
T_3 (Dry Pheromone Trap)	L_1 (Upper canopy)	2.67 bc
	L_2 (Canopy level)	3.67 b
	L_3 (Lower canopy	3.33 b
CV (%)		25.37
LSD (0.05)		1.29

[In columns, each mean is the average of three replicates and the same letter with means indicate the statistically similar with each other at 5% level of significance with DMRT]

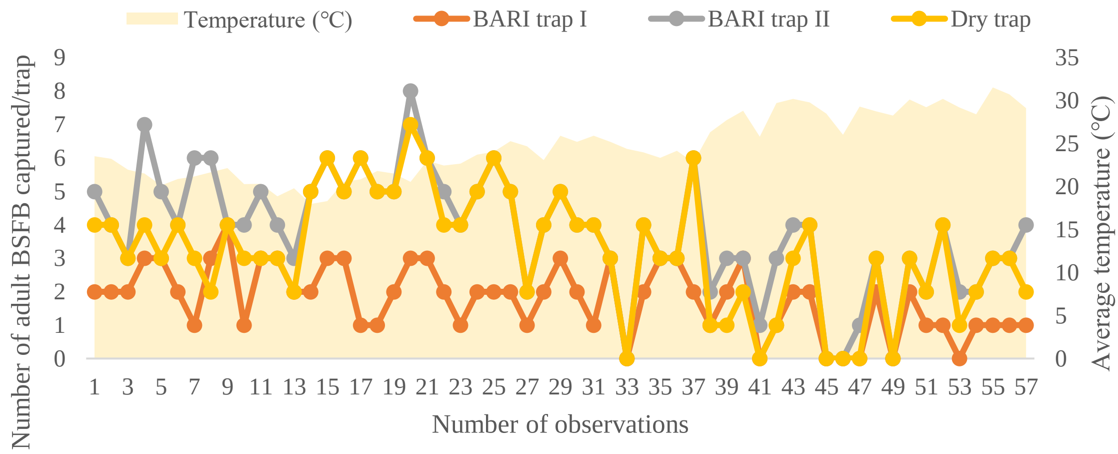
4.3.2. Influence of weather parameters on capturing capacity of pheromone trap

(a) Effect of rainfall: There was significant effect of rainfall on the incidence of BSFB. From the Figure 4.3.3. it can be revealed that, the number of BSFB reduced when the amount of rainfall was increased. At the same time, the number of BSFB was increased when the amount of rainfall was 0mm. In the present study, the negative relationship between the number of BSFB and rainfall was shown in the Figure 4.3.3.



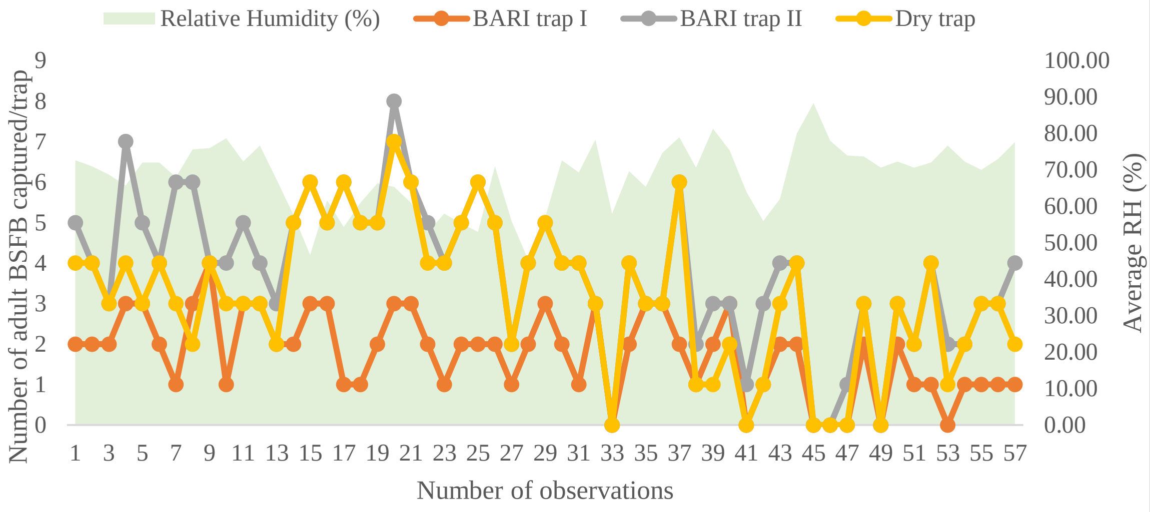
Figurer 4.3.3: Effect of rainfall on capturing BSFB by different types of traps

(b) Effect of temperature: There was significant effect of average temperature on the incidence of BSFB. From the Figure 4.3.4. it can be revealed that, the number of BSFB reduced when the average temperature was increased. At the same time, the number of BSFB was increased when the average temperature was reduced. In the present study, the negative relationship between the number of BSFB and the average temperature was shown in the Figure 4.3.4.



Figurer 4.3.4: Effect of temperature on capturing BSFB by different types of traps

(c) Effect of relative humidity: There was significant effect of relative humidity on the incidence of BSFB. From the Figure 4.3.5. it can be revealed that, the number of BSFB reduced when the percent relative humidity was increased. At the same time, the number of BSFB was increased when the percent relative humidity was reduced. In the present study, the negative relationship between the number of BSFB and percent relative humidity was shown in the Figure 4.3.5.



Figurer 4.3.5: Effect of relative humidity on capturing BSFB by different types of traps

4.3.3. Effect of types and setting position of pheromone traps on shoot infestation

(a) Effect of trap types on shoot infestation: The significant vatiations were observed among three types of pheromone traps in terms of shoot infestation per plant. From the findings it was revealed that the highest 29.72 percent shoot infestation was found in the brinjal plot where BARI Trap I was set for capturing adult BSFB moths and it was statistically different from other Trap types followed by Dry Trap (28.73% shoot infestation). On the flip side, the lowest shoot infestation was found in the brinjal plot where set BARI Trap II (24.13%) that was statistically different from other trap types also. From the above findings it was revealed that the BARI Trap II performed the best results in terms of showing the lowest shoot infestation in brinjal field than that of other two types of pheromone traps (Table-4.3.2).

(b) Effect of setting position of traps on shoot infestation: The significant vatiations were observed among three setting positions of pheromone traps in terms of shoot infestation per plot. From the findings it was revealed that the highest 30.01 percent shoot infestation was found when the pheromone trap was set at upper canopy level in the brinjal field, which was statistically different from other setting positions of pheromone traps but followed by lower canopy level that caused 27.36% shoot infestation. On the other hand, the lowest shoot infestation (25.75%) was found when pheromone trap was set at the canopy level in the brinjal field that was statistically similar with lower canopy level.

From the above finding it was revealed that the optimal trap height is very important to control BSFB. In the present investigation we found that the pheromone traps setting at different heights significantly influenced the shoot infestation by BSFB. The Pheromone Trap set at canopy level performed the best results in terms of showing lowest shoot infestation in brinjal field than that of other two setting positions of the pheromone traps (Table-4.3.2). Similar results were obtained by Cork *et al.,* 2003. They opined that the traps placed at crop canopy level caught more male moths than traps placed 0.5 m above or below the crop canopy in Bangladesh. The highest catch of adult BSFB was observed at plant canopy resulting in minimum shoot infestation (Alam *et al.*, 2003).

(c) Interaction effect of pheromone types and setting position on shoot infestation

From the findings of combined effect of trap types and setting position, statistical variations were observed among different types pheromone traps along with their setting position in the brinjal field in terms of shoot infestation caused by BSFB. The highest 51.97 percent shoot infestation was recorded in T_1L_1 (i.e., BARI Trap I when set at the upper canopy level in brinjal field), which was statistically different from all other combination of types and setting positions of pheromone traps. This was followed by 44.03 percent shoot infestation recorded in T_3L_1 (i.e., Dry Pheromone Trap set at upper canopy level) that was also statistically different from other combinations but followed by 34.99 percent shoot infestation recorded in T_1L_3 (i.e., BARI Trap I when set at lower canopy level) that was statistically similary with T_2L_1 (33.83%) followed by T_3L_3 (32.63%). On the other hand, the lowest 10.0 percent shoot infestation was found in T_2L_2 (i.e., BARI Trap II when set at canopy level in the brinjal field), which was statistically different from other combinations of trap types and their setting positions, but followed by 13.68 percent shoot infestation recorded in T_2L_3 (i.e., BARI Trap II when set at lower canopy level) which was also statistically different from other combinations of trap types and their setting positions but followed 18.97 percent shoot infestation recorded in T_3L_2 (i.e., Dry Pheromone Trap when set at canopy level) that was also statistically different from other combinations but followed by 34.99 percent shoot infestation recorded in T_1L_3 (i.e., BARI Trap I when set at lower canopy level) that was statistically different from other combinations but followed by 23.99 percent shoot infestation recorded in T_1L_2 (i.e., BARI Trap I when set at canopy level) (Table-4.3.2).

From the above findings it was revealed that the BARI Trap II showed the best performance in causing the lowest shoot infestation (10.0 percent) when it was set at canopy level in the brinjal field rather than other types of pheromone traps and any other setting positions.

Table-4.3.2. Effect of types and setting positions of pheromone traps on shoot infestation caused by BSFB

Sl. No.	Types of Pheromone Trap	Setting Position	No. of total shoot per plant	No. of infested shoot per plant	% Shoot infestation
(a)	**Effect of types of pheromone traps on shoot infestation caused by BSFB**				
	T_1 (BARI Trap I)	-	8.31 b	2.47 a	29.72 a
	BARI Trap II	-	8.62 a	2.08 c	24.13 c
	Dry Pheromone Trap	-	8.32 b	2.39 b	28.73 b
	$LSD_{(0.05)}$		0.17	0.07	0.94
	CV (%)		3.50	4.89	5.56
(b)	**Effect of different setting position of pheromone traps on shoot infestation caused by BSFB**				
	-	L_1 (Upper canopy)	8.23 b	2.47 a	30.01 a
	-	L_2 (Canopy level)	8.66 a	2.23 b	25.75 b
	-	L_3 (Lower canopy)	8.37 ab	2.29 b	27.36 b
	$LSD_{(0.05)}$		0.30	0.11	1.63
	CV (%)		3.50	4.89	5.56
(c)	**Interaction effect of types and setting position of pheromone traps on shoot infestation caused by BSFB**				
	T_1 (BARI Trap I)	L_1 (Upper canopy)	6.60 e	3.43 a	51.97 a
		L_2 (Canopy level)	9.17 b	2.20 e	23.99 e
		L_3 (Lower canopy)	7.63 cd	2.67 c	34.99 c
	T_2 (BARI Trap II)	L_1 (Upper canopy)	8.07 c	2.73 c	33.83 c
		L_2 (Canopy level)	10.70 a	1.07 h	10.00 h
		L_3 (Lower canopy)	9.50 b	1.30 g	13.68 g
	T_3 (Dry Pheromone Trap)	L_1 (Upper canopy)	7.20 d	3.17 b	44.03 b
		L_2 (Canopy level)	9.33 b	1.77 f	18.97 f
		L_3 (Lower canopy)	7.57 cd	2.47 d	32.63 d
	$LSD_{(0.05)}$		0.51	0.20	2.83
	CV (%)		3.50	4.89	5.56

[In columns, each mean is the average of three replicates and the same letter with means indicate the statistically similar with each other at 5% level of significance with DMRT]

4.3.4. Effect of types and setting position of pheromone traps on fruit infestation

(a) Effect of trap types on fruit infestation: The significant vatiations were observed among three types of pheromone traps in terms of fruit infestation both by number and weight. The highest 41.85 and 71.31 percent fruit infestation by number and weight, respectively were found in the brinjal plot where BARI Trap I was set for capturing adult BSFB moths and it was statistically different from other Trap types followed by Dry Trap (31.02 and 32.55% fruit infestation by number and weight, respectively). On the other hand, the lowest 21.23 and 15.25 percent fruit infestation by number and weight, respectively were found in the brinjal plot where BARI Trap II was set for capturing adult BSFB moths that was also statistically different from other trap types.

From the above findings it was revealed that the BARI Trap II performed the best results in terms of the lowest fruit infestation by both number and weight than that of other two types of pheromone traps (Table-4.3.3).

(b) Effect of setting position of traps on fruit infestation: The significant vatiations were also observed among three setting positions of pheromone traps in terms of fruit infestation by number and weight. From the findings it was revealed that the highest 44.97 and 38.04 percent fruit infestation by number and weight, respectively were found when the pheromone trap was set at upper canopy level in the brinjal field, which was statistically different from other setting positions of pheromone traps but followed by 39.35 and 30.56 percent fruit infestation by number and weight froun in the brinjal field where the pheromone trap was set at lower canopy level. On the other hand, the lowest 14.70 and 23.39 percent fruit infestation by number and weight, respectively were found when the pheromone trap was set at the canopy level in the brinjal field that was statistically different from all other setting positions of pheromone traps.

From the above findings it was revealed that the Pheromone Trap set at canopy level performed the best results in terms of producing lowest fruit infestation by both number and weight of brinjal than that of other two setting positions of the pheromone traps (Table-4.3.3). The present observations are also in agreement with the findings of Chakraborti (2001), Alam *et al.* (2006). They cited that application of pheromones in the management of BSFB was found highly effective and reduced shoot and fruit infestation and recorded higher fruit yield in brinjal. Parallel results were also asserted by Mazumder and Khalequzzaman (2010) on pheromone traps against the same pest. Similar results were also obtained by (Cork *et al.*, 2003). They opined that the traps placed at crop canopy level caught more male moths than traps placed 0.5 m above or below the crop canopy in Bangladesh (Cork *et al.*, 2003).

(c) Interaction effect of pheromone types and setting position on fruit infestation

From the findings of combined effect of trap types and setting position, statistical variations were observed among different types pheromone traps along with their setting position in the brinjal field in terms of shoot infestation caused by BSFB. The highest 70.84 and 88.30 percent fruit infestation by both number and weight were found in T_1L_1 (i.e., BARI Trap I when set at the upper canopy level in brinjal field), which was statistically different from all other combination of trap types and setting positions. This was followed by 50.01 and 69.64 percent fruit infestation by number and weight found in T_3L_1 (i.e., Dry Pheromone Trap set at upper canopy level) that was also statistically different from other combinations of traps and setting positions, but followed by 40.16 and 52.74 percent fruit infestation by number and weight, respectively were found in T_1L_3 (i.e., BARI Trap I when set at lower canopy level) that was statistically similary with T_2L_1 (39.64 and 51.88 percent fruit infestation by number and weight, respectively) followed by T_3L_3 (37.61 and 40.94% fruit infestation, respectively by number and weight). On the other hand, the lowest 8.08 and 9.44 percent fruit infestation by number and weight, respectively were found in T_2L_2 (i.e., BARI Trap II when set at canopy level in the brinjal field), which was statistically different from other combinations of trap types and their setting positions, but followed by 16.46 and 16.29 percent fruit infestation by number and weight were found in T_2L_3 combination (i.e., BARI Trap II when set at lower canopy level) which was followed 20.85 and 19.79 percent fruit infestation by number and weight found in T_3L_2 (i.e., Dry Pheromone Trap when set at canopy level) and T_1L_2 (29.99 and 26.30 percent fruit infestation by number and weight, respectively) (Table-4.3.3).

From the above findings it was revealed that the BARI Trap II showed the best performance resulting lowest fruit infestation (8.08 and 9.44 percent, respectivly) by both number and weight when it was set at canopy level in the brinjal field rather than other types of pheromone traps and any other setting positions.

Table-4.3.3. Effect of types and setting positions of pheromone traps on fruit infestation by number caused by BSFB

Sl. No.	Types of Pheromone Trap	Setting Position	% Fruit infestation by number	% Fruit infestation by weight
(a)	**Effect of types of pheromone traps on fruit infestation**			
	T_1 (BARI Trap I)	-	41.85 a	71.31 a
	BARI Trap II	-	21.23 c	15.25 c
	Dry Pheromone Trap	-	31.02 b	32.55 b
	$LSD_{(0.05)}$		1.02	1.98
	CV (%)		3.07	3.07
(b)	**Effect of setting positions of pheromone traps on fruit infestation**			
	-	L_1 (Upper canopy)	44.97a	38.04a
	-	L_2 (Canopy level)	14.70c	23.39c
	-	L_3 (Lower canopy)	39.35b	30.56b
	$LSD_{(0.05)}$		1.64	1.77
	CV (%)		2.85	3.07
(c)	**Interaction effect of types and setting positions of pheromone traps on fruit infestation**			
	T_1 (BARI Trap I)	L_1 (Upper canopy)	70.84 a	88.30 a
		L_2 (Canopy level)	24.99 e	26.30 e
		L_3 (Lower canopy)	40.16 c	52.74 c
	T_2 (BARI Trap II)	L_1 (Upper canopy)	39.64 c	51.88 c
		L_2 (Canopy level)	8.08 h	9.44 g
		L_3 (Lower canopy)	16.46 g	16.29 f
	T_3 (Dry Pheromone Trap)	L_1 (Upper canopy)	50.01 b	69.64 b
		L_2 (Canopy level)	20.85 f	19.79 f
		L_3 (Lower canopy)	37.61 d	40.94 d
	$LSD_{(0.05)}$		5.15	5.94
	CV (%)		3.07	3.07

[In columns, each mean is the average of three replicates and the same letter with means indicate the statistically similar with each other at 5% level of significance with DMRT]

4.3.5. Effect of types and setting position of pheromone traps on fruit yield

(a) Effect of trap types on fruit yield: The significant vatiations were observed among three types of pheromone traps in terms of producing brinjal fruit yield. The highest 7.76 kg/plot (10.35 ton/ha) fruit yield was produced in the brinjal plot where BARI Trap II was set for capturing adult BSFB moths and it was statistically different from other Trap types followed by Dry Trap (6.33 kg/plot and 8.44 ton/ha, respectively). On the other hand, the lowest 4.74 kg/plot (6.32 ton/ha) fruit yield was found in the brinjal plot where BARI Trap I was set for capturing adult BSFB moths that was also statistically different from other trap types.

From the above findings it was revealed that the BARI Trap II performed the best results in terms of production of fruit yield than that of other two types of pheromone traps (Table-4.3.4).

(b) Effect of setting position of traps on fruit yield: The significant vatiations were also observed among three setting positions of pheromone traps in terms of producing brinjal fruit yield. From the findings it was revealed that the highest 7.01 kg/plot (9.35 ton/ha) fruit yield was produced in the plot where the pheromone trap was set at upper canopy level in the brinjal field, which was statistically different from other setting positions of pheromone traps but followed by 6.16 kg/plot (8.21 ton/ha) fruit yield was froun in the brinjal field where the pheromone trap was set at lower canopy level. On the other hand, the lowest 5.66 kg/plot (7.55 ton/ha) fruit yield was found when the pheromone trap was set at the canopy level in the brinjal field that was statistically different from all other setting positions of pheromone traps.

From the above findings it was revealed that the Pheromone Trap set at canopy level performed the best results in terms of producing highest brinjal fruit yield (Table-4.3.4).

(c) Interaction effect of pheromone types and setting position on fruit infestation

From the findings of combined effect of trap types and setting position, statistical variations were observed among different types pheromone traps along with their setting position in the brinjal field in terms of fruit yield. The highest 8.90 kg/plot (11.86 ton/ha) fruit yield was found in T_2L_2 (i.e., BARI Trap II when set at the canopy level in brinjal field), which was statistically different from all other combination of trap types and setting positions. This was followed by 7.26 kg/plot (9.68 ton/ha) fruit yield found in T_2L_3 (i.e., BARI Trap II set at lower canopy level) that was also statistically different from other combinations of traps and setting positions, but followed by 7.13 kg/plot (9.51 ton/ha) fruit yield was found in T_3L_2 (i.e., Dry Pheromone Trap when set at canopy level) that was statistically different from other combinations and followed by T_1L_2 (6.95 kg/plot or 9.27 ton/ha) followed by T_2L_1 (6.31 kg/plot). On the other hand, the lowest 4.13 kg/plot (5.60 ton/ha) fruit yield was found in T_1L_1 (i.e., BARI Trap I when set at upper canopy level in the brinjal field), which was statistically different from other combinations of trap types and their setting positions, but followed by 4.92 kg/plot (6.56 ton/ha) fruit yield was found in T_3L_1 combination (i.e., Dry Pheromone Trap when set at upper canopy level) which was followed by 5.18 kg/plot (6.91 ton/ha) fruit yield which was found in T_1L_3 (i.e., BARI Trap I when set at lower canopy level) and T_3L_3 (5.73 kg/plot and 7.64 ton/ha) fruit yield. (Table-4.3.4).

From the above findings it was revealed that the BARI Trap II showed the best performance in producing highest fruit yield when it was set at canopy level in the brinjal field rather than other types of pheromone traps and any other setting positions.

Table-4.3.4. Effect of types and setting positions of pheromone traps on fruit yield of brinjal

Sl. No.	Types of Pheromone Trap	Setting Position	Fruit yield (kg/plot)	Fruit yield (ton/ha)
(a)	**Effect of types of pheromone traps on fruit infestation**			
	T_1 (BARI Trap I)	-	4.74 c	6.32 c
	BARI Trap II	-	7.76 a	10.35 a
	Dry Pheromone Trap	-	6.33 b	8.44 b
	$LSD_{(0.05)}$		0.02	1.03
	CV (%)		0.51	0.63
(b)	**Effect of setting positions of pheromone traps on fruit infestation**			
	-	L_1 (Upper canopy)	5.66 c	7.55 c
	-	L_2 (Canopy level)	7.01 a	9.35 a
	-	L_3 (Lower canopy)	6.16 b	8.21 b
	$LSD_{(0.05)}$		0.03	0.51
	CV (%)		0.51	0.63
(c)	**Interaction effect of types and setting positions of pheromone traps on fruit infestation**			
	T_1 (BARI Trap I)	L_1 (Upper canopy)	4.13 i	5.50 i
		L_2 (Canopy level)	6.95 d	9.27 d
		L_3 (Lower canopy)	5.18 g	6.91 g
	T_2 (BARI Trap II)	L_1 (Upper canopy)	6.31 e	8.41 e
		L_2 (Canopy level)	8.90 a	11.86 a
		L_3 (Lower canopy)	7.26 b	9.68 b
	T_3 (Dry Pheromone Trap)	L_1 (Upper canopy)	4.92 h	6.56 h
		L_2 (Canopy level)	7.13 c	9.51 c
		L_3 (Lower canopy)	5.73 f	7.64 f
	$LSD_{(0.05)}$		0.06	0.13
	CV (%)		0.51	0.63

[In columns, each mean is the average of three replicates and the same letter with means indicate the statistically similar with each other at 5% level of significance with DMRT]

Experiment-4: Effectiveness of botanicals and other non-chemical approaches against BSFB in comparison with chemical insecticides

This chapter comprises the effectiveness of botanicals and other non-chemical approaches against BSFB in comparison with chemical insecticides. The data have been presented and discussed and possible interpretations are made under the following sub-headings:

4.4.1. Effect on shoot infestation

The significant variations were observed among the treatments in terms of shoot infestation per brinjal plant (Table 4.4.1). From the findings it was revealed that the highest shoot infestation (46.23%) was recorded in the brinjal plot where no control measure (T_8) was taken for controlling BSFB, which was statistically different from others, followed by T_3 (42.43), T_5 (38.17), T_2 (31.43) and T_7 (26.96%). On the other hand, the lowest percent shoot infestation by number (10.79%) was recorded in the brinjal plot where Marshal 20 EC (T_6) was used for controlling BSFB at 7 days interval with a rate of 3.0 ml/L, which was statistically different from others and followed by T_4 (18.22) and T_1 (22.50%).

Considering the reduction of shoot infestation, the highest reduction of shoot infestation over control was observed (76.66%) in T_6, followed by T_4 (60.59), T_1 (51.33) and T_7 (41.68%). Whereas the lowest reduction of shoot infestation over control was observed in T_3 (8.22%), followed by T_5 (17.43) and T_2 (32.01%) (Table 4.4.1).

From the above finding it was revealed that the lowest shoot infestation (10.79%) (number) was recorded in treatment T_6 comprised of spraying of Marshal 20 EC @ 3.0 ml/L of water at 7 days interval. As a result, the order of efficacy of management practices in terms of shoot infestation (number) is $T_6 > T_4 > T_1 > T_7 > T_2 > T_5 > T_3 > T_8$. Similar results were obtained by Nenavati and Kumar (2014) and Dutta *et al.* (2011). They opined that Carbosalfan was most effective to reduce shoot infestation caused by BSFB.

Table 4.4.1: Effect of different treatments on shoot infestation caused by BSFB

Treatments	No. of shoot per plant	No. of infested shoot per plant	% Shoot infestation	% Reduction over control
T_1	11.07 b	2.63 e	22.50 f	51.33
T_2	9.33 cd	3.00 d	31.43 d	32.01
T_3	8.57 d	3.63 ab	42.43 b	8.22
T_4	11.53 b	2.47 f	18.22 g	60.59
T_5	8.73 d	3.33 c	38.17 c	17.43
T_6	12.67 a	2.10 g	10.79 h	76.66
T_7	9.77 c	2.93 d	26.96 e	41.68
T_8	8.37 e	3.87 a	46.23 a	0
CV (%)	5.84	3.17	4.98	-
$LSD_{(0.05)}$	0.92	0.16	2.53	-

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT).

Here, T_1= Spraying of Neem oil (Azadirachtin) @ 3.0 ml/L of water at 7 days interval, T_2= Spraying of Neem seed kernel extract (Azadirachtin) (@ 3.0 ml/L of water at 7 days interval, T_3= Collection and destruction of infested shoots and fruits, T_4= Pheromone trap located at the canopy level @ 1 lure at 30 days interval, T_5= Spraying of Tracer 45 SC (Spinosad) @ 0.4 ml/L of water at 7 days interval, T_6= Spraying of Marshal 20 EC (Carbosulfan) @ 3.0 ml/L of water at 7 days interval, T_7= Spraying of Suntap 50 SP (Cartap) @ 1.5 g/L of water at 7 days interval, T_8= Untreated control]

4.4.2. Fruit infestation (number)

The effect of management practices on the percent fruit infestation by number has been shown in Table 4.4.2. Significant variations were observed among the treatments in terms of percent fruit infestation by number of brinjal. The highest percent fruit infestation by number (59.89%) was recorded in treatment T_8 (untreated control), which was statistically different from others, followed by T_3 (52.87), T_5 (43.42), T_2 (38.64) and T_7 (36.30%). On the other hand, the lowest percent fruit infestation by number (13.91%) was recorded in the brinjal plot where Marshal 20 EC (T_6) was used for controlling BSFB at 7 days interval with a rate of 3.0 ml/L, which was statistically different from others and followed by T_4 (23.35) and T_1 (26.44%).

Considering the reduction of fruit infestation (number), the highest reduction of fruit infestation (number) over control was observed (76.77%) in T_6, followed by T_4 (61.01), T_1 (55.85) and T_7 (39.39%). Whereas the lowest reduction of fruit infestation (number) over control was observed in T_3 (11.72%), followed by T_5 (27.50) and T_2 (35.48%) (Table 4.4.2).

Table 4.4.2: Effect of different treatments on fruit infestation by number caused by BSFB

Treatments	Number of fruit	Number of infested fruit	% Fruit infestation	% Reduction over control
T_1	51.67 c	13.67 e	26.44 e	55.85
T_2	43.00 e	17.67 c	38.64 d	35.48
T_3	41.00 f	21.67 b	52.87 b	11.72
T_4	54.33 b	12.67 e	23.35 f	61.01
T_5	42.33 e	18.67 c	43.42 c	27.50
T_6	62.33 a	8.67 f	13.91 g	76.77
T_7	48.67 d	16.33 d	36.30 d	39.39
T_8	37.67 g	22.33 a	59.89 a	0
CV (%)	3.13	4.30	6.02	-
$LSD_{(0.05)}$	2.24	1.18	4.11	-

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT).

Here, T_1= Spraying of Neem oil (Azadirachtin) @ 3.0 ml/L of water at 7 days interval, T_2= Spraying of Neem seed kernel extract (Azadirachtin) (@ 3.0 ml/L of water at 7 days interval, T_3= Collection and destruction of infested shoots and fruits, T_4= Pheromone trap located at the canopy level @ 1 lure at 30 days interval, T_5= Spraying of Tracer 45 SC (Spinosad) @ 0.4 ml/L of water at 7 days interval, T_6= Spraying of Marshal 20 EC (Carbosulfan) @ 3.0 ml/L of water at 7 days interval, T_7= Spraying of Suntap 50 SP (Cartap) @ 1.5 g/L of water at 7 days interval, T_8= Untreated control]

From the above findings it was revealed that the lowest fruit infestation (13.91%) (number) was recorded in treatment T_6 comprised of spraying of Marshal 20 EC @ 0.1 ml/L of water at 7 days interval. As a result, the order of efficacy of management practices in terms of fruit infestation (number) is $T_6>T_4>T_1>T_7>T_2>T_5>T_3>T_8$. Similar results were obtained by Nenavati and Kumar (2014) and Dutta *et al.* (2011). They opined that Carbosalfan was most effective to reduce fruit infestation by number caused by BSFB.

4.4.3. Fruit infestation (weight)

The effect of management practices on the percent fruit infestation by weight has been shown in Table 4.4.3. Significant variations were observed among the treatments in terms of percent fruit infestation by weight of brinjal. The highest percent fruit infestation by weight (63.37%) was recorded in the brinjal plot where no control measure (T_8) was taken for controlling BSFB, which was statistically different from others, followed by T_3 (54.42), T_5 (48.76), T_2 (43.45) and T_7 (35.65%). On the other hand, the lowest percent fruit infestation by weight (13.96%) was recorded in treatment T_6, (Marshal 20 EC @ 3.0 ml/L at 7 days interval) which was statistically different from others and followed by T_4 (24.67) and T_1 (30.66%).

Considering the reduction of fruit infestation (weight), the highest reduction of fruit infestation (weight) over control was observed (77.97%) in T_6, followed by T_4 (61.07), T_1 (51.62) and T_7 (43.74%). Whereas the lowest reduction of fruit infestation (weight) over control was observed in T_3 (14.12%), followed by T_5 (23.06) and T_2 (31.43%) (Table 4.4.3).

Table 4.4.3: Effect of different treatments on fruit infestation by weight caused by BSFB

Treatments	Weight of fruit (kg)	Weight of infested fruit (kg)	Weight of healthy fruit (kg)	% fruit infestation	% Reduction over control
T_1	3.00 c	1.06 f	2.16 c	30.66 f	51.62
T_2	2.64 d	1.25 d	1.49 e	43.45 d	31.43
T_3	2.45 f	1.45 b	1.12 g	54.42 b	14.12
T_4	3.11 b	0.95 g	2.50 b	24.67 g	61.07
T_5	2.56 e	1.33 c	1.31 f	48.76 c	23.06
T_6	3.32 a	0.82 h	3.50 a	13.96 h	77.97
T_7	2.96 c	1.15 e	1.91 d	35.65 e	43.74
T_8	2.29 g	1.74 a	0.84 h	63.37 a	0
CV (%)	1.03	2.46	2.21	2.55	-
$LSD_{(0.05)}$	0.05	0.05	0.08	1.76	-

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT).

Here, T_1= Spraying of Neem oil (Azadirachtin) @ 3.0 ml/L of water at 7 days interval, T_2= Spraying of Neem seed kernel extract (Azadirachtin) (@ 3.0 ml/L of water at 7 days interval, T_3= Collection and destruction of infested shoots and fruits, T_4= Pheromone trap located at the canopy level @ 1 lure at 30 days interval, T_5= Spraying of Tracer 45 SC (Spinosad) @ 0.4 ml/L of water at 7 days interval, T_6= Spraying of Marshal 20 EC (Carbosulfan) @ 3.0 ml/L of water at 7 days interval, T_7= Spraying of Suntap 50 SP (Cartap) @ 1.5 g/L of water at 7 days interval, T_8= Untreated control]

From the above findings it was revealed that the lowest fruit infestation (13.96%) (weight) was recorded in treatment T_6 comprised of spraying of Marshal 20 EC @ 0.1 ml/L of water at 7 days interval. As a result, the order of efficacy of management practices in terms of fruit infestation (weight) is $T_6>T_4>T_1>T_7>T_2>T_5>T_3>T_8$. Similar results were obtained by Nenavati and Kumar (2014) and Dutta *et al.* (2011). They opined that Carbosalfan was most effective to reduce fruit infestation by weight caused by BSFB.

4.4.4. Yield attributing characteristics of brinjal

Length of healthy fruit: The effect of management practices on the length of healthy fruit has been shown in Table 4.4.4. Significant variations were observed among the treatments in terms of length of healthy fruits. The highest length of healthy fruit plot^{-1} (8.72 cm) was recorded in treatment T_6, which was statistically different from others, followed by T_4 (8.36), T_1 (8.06) and T_7 (7.91 cm). On the other hand, the lowest length of healthy fruit plot^{-1} (6.87 cm) was recorded in treatment T_8, which was statistically different from others and followed by T_3 (7.14), T_5 (7.36) and T_2 (7.55 cm).

Girth of healthy fruit: The effect of management practices on the girth of healthy fruit has been shown in Table 4.4.4. Significant variations were observed among the treatments in terms of girth of healthy fruits. The highest girth of healthy fruit plot^{-1} (21.75 cm) was recorded in treatment T_6, which was statistically different from others, followed by T_4 (20.16), T_1 (19.45) and T_7 (19.35 cm). On the other hand, the lowest girth of healthy fruit plot^{-1} (18.16 cm) was recorded in treatment T_8, which was statistically different from others and followed by T_3 (18.34), T_5 (18.75) and T_2 (19.16 cm).

Length of infested fruit: The effect of management practices on the length of infested fruit has been shown in Table 4.4.4. Significant variations were observed among the treatments in terms of length of infested fruits. The highest length of infested fruit plot^{-1} (5.85 cm) was recorded in treatment T_6, which was statistically different from others, followed by T_4 (5.24), T_1 (4.94) and T_7 (4.62 cm). On the other hand, the lowest length of infested fruit plot^{-1} (3.42 cm) was recorded in treatment T_8, which was statistically different from others and followed by T_3 (3.74), T_5 (4.15) and T_2 (4.22 cm).

Girth of infested fruit: The effect of management practices on the girth of infested fruit has been shown in Table 4.4.4. Significant variations were observed among the treatments in terms of girth of infested fruits. The highest girth of infested fruit plot^{-1} (14.02 cm) was recorded in treatment T_6, which was statistically different from others, followed by T_4 (13.84), T_1 (13.66) and T_7 (13.46 cm). On the other hand, the lowest girth of infested fruit plot^{-1} (12.35 cm) was recorded in treatment T_8, which was statistically different from others and followed by T_3 (12.85), T_5 (12.99) and T_2 (13.20 cm).

Table 4.4.4: Effect of different treatments on yield attributing characteristics of brinjal

Treatments	Length of healthy fruit (cm)	Girth of healthy fruit (cm)	Length of infested fruit (cm)	Girth of infested fruit (cm)
T_1	8.06 c	19.45 c	4.94 c	13.66 c
T_2	7.55 e	19.16 e	4.22 e	13.20 e
T_3	7.14 g	18.34 g	3.74 g	12.85 g
T_4	8.36 b	20.16 b	5.24 b	13.84 b
T_5	7.36 f	18.75 f	4.15 f	12.99 f
T_6	8.72 a	21.75 a	5.85 a	14.02 a
T_7	7.91 d	19.35 d	4.62 d	13.46 d
T_8	6.87 h	18.16 h	3.42 h	12.35 h
CV (%)	0.44	0.18	0.62	0.28
$LSD_{(0.05)}$	0.05	0.05	0.05	0.05

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT).

Here, T_1= Spraying of Neem oil (Azadirachtin) @ 3.0 ml/L of water at 7 days interval, T_2= Spraying of Neem seed kernel extract (Azadirachtin) (@ 3.0 ml/L of water at 7 days interval, T_3= Collection and destruction of infested shoots and fruits, T_4= Pheromone trap located at the canopy level @ 1 lure at 30 days interval, T_5= Spraying of Tracer 45 SC (Spinosad) @ 0.4 ml/L of water at 7 days interval, T_6= Spraying of Marshal 20 EC (Carbosulfan) @ 3.0 ml/L of water at 7 days interval, T_7= Spraying of Suntap 50 SP (Cartap) @ 1.5 g/L of water at 7 days interval, T_8= Untreated control]

From the above findings it was revealed that the highest length of healthy fruit, girth of healthy fruit, length of infested fruit and girth of infested fruit (8.72, 21.75, 5.85 and 14.02 cm, respectively) was recorded in treatment T_6 comprised of spraying of Marshal 20 EC @ 0.1 ml/L of water at 7 days interval. As a result, the order of efficacy of management practices in terms of length of healthy fruit, girth of healthy fruit, length of infested fruit and girth of infested fruit is $T_6>T_4>T_1>T_7>T_2>T_5>T_3>T_8$. Similar results were obtained by Islam *et al.* (2004). They opined that Carbosalfan was most effective to prevent reduced fruit length and girth infested by BSFB.

Number of bore: The effect of management practices on the number of bore per fruit has been shown in Table 4.4.5. Significant variations were observed among the treatments in terms of number of bores per fruits. The lowest number of bores fruit^{-1} (2.67 bores) was recorded in treatment T_6, which was statistically similar with T_4 (3.00) and T_1 (3.00) and followed by T_7 (3.33 bores). On the other hand, the highest number of bores fruit^{-1} (6.33 bores) was recorded in treatment T_8, which was statistically different from others and followed by T_3 (4.67), T_5 (4.00) and T_2 (3.67 bores).

Weight of edible portion: The effect of management practices on the weight of edible portion of infested fruit has been shown in Table 4.4.5. Significant variations were observed among the treatments in terms of weight of edible portion of infested fruits. The highest weight of edible portion of infested fruit (3.00 g) was recorded in treatment T_6, which was statistically different from others, followed by T_4 (0.45), T_1 (0.43) and T_7 (0.41 g). On the other hand, the lowest weight of edible portion of infested fruit (0.33 g) was recorded in treatment T_8, which was statistically similar with T_3 (0.35), T_5 (0.37) and T_2 (0.38 g).

Weight of non-edible portion: The effect of management practices on the weight of non-edible portion of infested fruit has been shown in Table 4.4.5. Significant variations were observed among the treatments in terms of weight of non-edible portion of infested fruits. The highest weight of non-edible portion of infested fruit (1.45 g) was recorded in treatment T_8, which was statistically different from others, followed by T_3 (1.15), T_5 (1.00) and T_2 (0.90 g). On the other hand, the lowest weight of non-edible portion of infested fruit (0.39 g) was recorded in treatment T_6, which was statistically different from others and followed by T_4 (0.54), T_1 (0.67) and T_7 (0.77 g).

From the above findings it was revealed that the lowest number of bores fruit^{-1}, highest weight of edible portion of infested fruit and lowest weight of non-edible portion of infested fruit (2.67 bores, 3.00 g/fruit and 0.39 g/fruit, respectively) were recorded in treatment T_6 comprised of spraying of Marshal 20 EC @ 0.1 ml/L of water at 7 days interval. As a result, the order of efficacy of management practices in terms of number of bores fruit^{-1}, weight of edible portion of infested fruit and weight of non-edible portion of infested fruit is $T_6>T_4>T_1>T_7>T_2>T_5>T_3>T_8$. Similar results were obtained by Yogi and Kumar (2010). They opined that Carbosalfan was most effective to reduce non-edible portion of infested fruits caused by BSFB.

Table 4.4.5: Effect of different treatments on yield attributing characteristics of brinjal

Treatments	Number of Bore per fruit	Edible fruit weight (g)	Non-edible fruit weight (g)
T_1	3.00 def	0.43 bc	0.67 f
T_2	3.67 cd	0.38 cd	0.90 d
T_3	4.67 b	0.35 de	1.15 b
T_4	3.00 def	0.45 b	0.54 g
T_5	4.00 bc	0.37 cd	1.00 c
T_6	2.67 ef	3.00 a	0.39 h
T_7	3.33 cde	0.41 bc	0.77 e
T_8	6.33 a	0.33 de	1.45 a
CV (%)	14.66	1.63	3.30
$LSD_{(0.05)}$	0.86	0.05	0.05

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT).

Here, T_1= Spraying of Neem oil (Azadirachtin) @ 3.0 ml/L of water at 7 days interval, T_2= Spraying of Neem seed kernel extract (Azadirachtin) (@ 3.0 ml/L of water at 7 days interval, T_3= Collection and destruction of infested shoots and fruits, T_4= Pheromone trap located at the canopy level @ 1 lure at 30 days interval, T_5= Spraying of Tracer 45 SC (Spinosad) @ 0.4 ml/L of water at 7 days interval, T_6= Spraying of Marshal 20 EC (Carbosulfan) @ 3.0 ml/L of water at 7 days interval, T_7= Spraying of Suntap 50 SP (Cartap) @ 1.5 g/L of water at 7 days interval, T_8= Untreated control]

4.4.5. Yield of brinjal

The effect of management practices on the yield of brinjal per plot has been shown in Table 4.4.6. Significant variations were observed among the treatments in terms of yield of brinjal per plot. The highest yield of brinjal plot^{-1} (8.84 kg) was recorded in the brinjal plot where Marshal 20 EC (T_6) was used for controlling BSFB at 7 days interval with a rate of 3.0 ml/L which was statistically different from others, followed by T_4 (8.33), T_1 (7.85) and T_7 (6.44 kg). On the other hand, the lowest yield of brinjal plot^{-1} (3.94 kg) was recorded in treatment T_8, which was statistically different from others and followed by T_3 (4.26), T_5 (4.60) and T_2 (5.75 kg).

Considering the increase of fruit yield, the highest increase of brinjal yield over control was observed (132.49%) in T_6, followed by T_4 (118.93), T_1 (106.31) and T_7 (69.40%).

Whereas the lowest increase of fruit yield over control was observed in T_3 (11.99%), followed by T_5 (20.98) and T_2 (51.10%) (Table 4.4.6).

From the above findings it was revealed that the highest yield of brinjal (8.84 kg/plot) as recorded in treatment T_6 comprised of spraying of Marshal 20 EC @ 0.1 ml/L of water at 7 days interval. As a result, the order of efficacy of management practices in terms of yield of brinjal is $T_6>T_4>T_1>T_7>T_2>T_5>T_3>T_8$. Similar results were obtained by Sabry *et al.* (2014); Hamdy and Sayed (2013); Chatterjee and Mondal (2012) and Shah *et al.* (2012). They opined that Carbosalfan was most effective to show high yield of brinjal.

Table 4.4.6: Effect of different treatments on yield of brinjal

Treatments	Yield/plant (Kg)	Yield/plot (Kg)	Yield/ha (ton)	% Increase over control
T_1	0.96 c	7.85 c	13.08 c	106.31
T_2	0.85 d	5.75 e	9.58 e	51.10
T_3	0.77 ef	4.26 g	7.10 g	11.99
T_4	1.07 b	8.33 b	13.88 b	118.93
T_5	0.82 de	4.60 f	7.67 f	20.98
T_6	1.15 a	8.84 a	14.74 a	132.49
T_7	0.93 c	6.44 d	10.74 d	69.40
T_8	0.74 fg	3.94 h	6.34 h	0
CV (%)	1.78	0.57	0.48	-
$LSD_{(0.05)}$	0.05	0.05	0.05	-

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT).

Here, T_1= Spraying of Neem oil (Azadirachtin) @ 3.0 ml/L of water at 7 days interval, T_2= Spraying of Neem seed kernel extract (Azadirachtin) (@ 3.0 ml/L of water at 7 days interval, T_3= Collection and destruction of infested shoots and fruits, T_4= Pheromone trap located at the canopy level @ 1 lure at 30 days interval, T_5= Spraying of Tracer 45 SC (Spinosad) @ 0.4 ml/L of water at 7 days interval, T_6= Spraying of Marshal 20 EC (Carbosulfan) @ 3.0 ml/L of water at 7 days interval, T_7= Spraying of Suntap 50 SP (Cartap) @ 1.5 g/L of water at 7 days interval, T_8= Untreated control]

4.4.6. Beneficial arthropods in brinjal field

Lady bird beetle: The effect of management practices on the number of lady bird beetle per plot of brinjal has been shown in Table 4.4.7. Significant variations were observed among the treatments in terms of number of lady bird beetle per plot of brinjal.

The highest number of lady bird beetle plot^{-1} (4.67 lady bird beetle) was recorded in treatment T_8, which was statistically different from others, followed by T_1 (3.67), T_2 (3.67) and T_5 (3.33 lady bird beetle). On the other hand, the lowest number of lady bird beetle plot^{-1} of brinjal (1.67 lady bird beetle) was recorded in treatment T_6, which was statistically similar with T_7 (2.00) and T_4 (2.33) and followed by T_3 (2.67 lady bird beetle).

Ant: The effect of management practices on the number of ant per plot of brinjal has been shown in Table 4.4.7. Significant variations were observed among the treatments in terms of number of ant per plot of brinjal. The highest number of ant plot^{-1} (5.67 ant) was recorded in treatment T_8, which was statistically similar with T_2 (5.33) and followed by T_4 (4.33) and T_5 (3.67 ant). On the other hand, the lowest number of ant plot^{-1} of brinjal (1.00 ant) was recorded in treatment T_6, which was statistically similar with T_7 (2.33) and followed by T_1 (2.67) and T_3 (3.33 ant).

Spider: The effect of management practices on the number of spider per plot of brinjal has been shown in Table 4.4.7. Significant variations were observed among the treatments in terms of number of spider per plot of brinjal. The highest number of spider plot^{-1} (4.33 spider) was recorded in treatment T_8, which was statistically different from other treatments and followed by T_2 (3.67), T_4 (3.33) and T_5 (2.67 spider). On the other hand, the lowest number of spider plot^{-1} of brinjal (1.33 spider) was recorded in treatment T_6, which was statistically different from others and followed by T_7 (1.67), T_1 (2.33) and T_3 (2.67 spider).

From the above findings it was revealed that the highest number of lady bird beetle, ant and spider (4.67 lady bird beetle, 5.67 ant and 4.33 spider, respectively) was recorded in treatment T_8 comprised of untreated control. As a result, the order of efficacy of management practices in terms of number of lady bird beetle, ant and spider is $T_8 > T_2 > T_4 > T_5 > T_3 > T_1 > T_7 > T_6$. Similar results were obtained by Sabry *et al.* (2014); Hamdy and Sayed (2013); Chatterjee and Mondal (2012); Aprana and Dethe (2012) and Shah *et al.* (2012). They opined that Neem oil showed the best performance to increase the incidence of natural enemies in the brinjal field.

Table 4.4.7: Effect of different treatments on number of beneficial arthropods per plot

Treatments	Lady bird beetle	Ant	Spider
T_1	3.67 b	2.67 cde	2.33 e
T_2	3.67 b	5.33 a	3.67 b
T_3	2.67 cde	3.33 cd	2.67 de
T_4	2.33 def	4.33 b	3.33 bc
T_5	3.33 bc	3.67 bc	2.67 de
T_6	1.67 f	1.00 f	1.33 g
T_7	2.00 ef	2.33 ef	1.67 f
T_8	4.67 a	5.67 a	4.33 a
CV (%)	17.86	12.94	14.50
$LSD_{(0.05)}$	0.85	0.73	0.65

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT).

Here, T_1= Spraying of Neem oil (Azadirachtin) @ 3.0 ml/L of water at 7 days interval, T_2= Spraying of Neem seed kernel extract (Azadirachtin) (@ 3.0 ml/L of water at 7 days interval, T_3= Collection and destruction of infested shoots and fruits, T_4= Pheromone trap located at the canopy level @ 1 lure at 30 days interval, T_5= Spraying of Tracer 45 SC (Spinosad) @ 0.4 ml/L of water at 7 days interval, T_6= Spraying of Marshal 20 EC (Carbosulfan) @ 3.0 ml/L of water at 7 days interval, T_7= Spraying of Suntap 50 SP (Cartap) @ 1.5 g/L of water at 7 days interval, T_8= Untreated control]

4.4.7. Relationship between shoot and fruit infestation and yield of brinjal

4.4.7.1. Fruit infestation by number

Correlation study was done to establish the relationship between the percent fruit infestation (number) and yield (kg/ton) of brinjal during the management of brinjal shoot and fruit borer by different botanicals and other chemical insecticides. From the study it was revealed that, significant correlation was observed between the fruit infestation by number and yield of brinjal (Figure 4.4.1). It was evident from the Figure 4.4.1 that the regression equation $y = -0.2062x + 17.99$ gave a good fit to the data, and the co-efficient of determination ($R^2 = 0.9519$) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a negative relationship between fruit infestation (number) and yield of brinjal, i.e., the yield decreased with the increase of the infestation of fruit (number) by brinjal shoot and fruit borer.

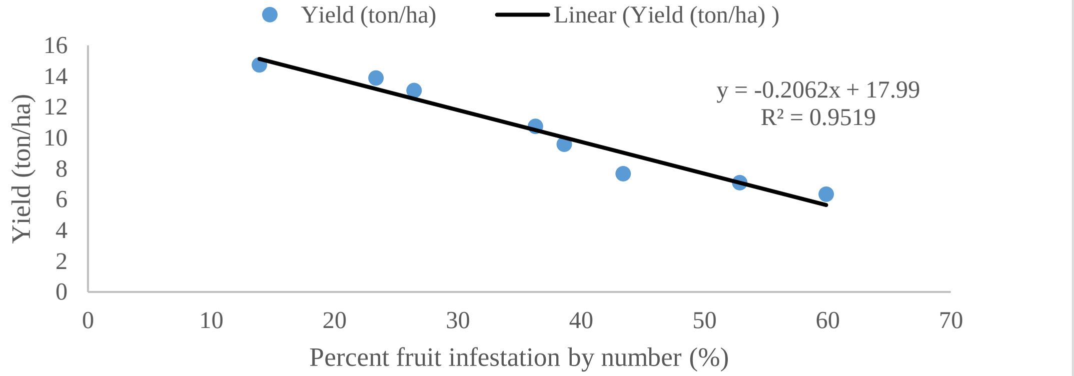


Figure 4.4.1. Relationship between yield (ton/ha) and percent fruit infestation by number (%) of brinjal caused by BSFB

4.4.7.2. Fruit infestation by weight

Correlation study was done to establish the relationship between the percent fruit infestation (weight) and yield (kg/plot) of brinjal during the management of brinjal shoot and fruit borer by different botanicals and other chemical insecticides. From the study it was revealed that, significant correlation was observed between the fruit infestation (weight) and yield of brinjal (Figure 4.4.2). It was evident from the Figure 4.4.2 that the regression equation y = -0.1948x + 18.061 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.9567) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a negative relationship between fruit infestation (weight) and yield of brinjal, i.e., the yield decreased with the increase of the infestation of fruit (weight) by brinjal shoot and fruit borer.

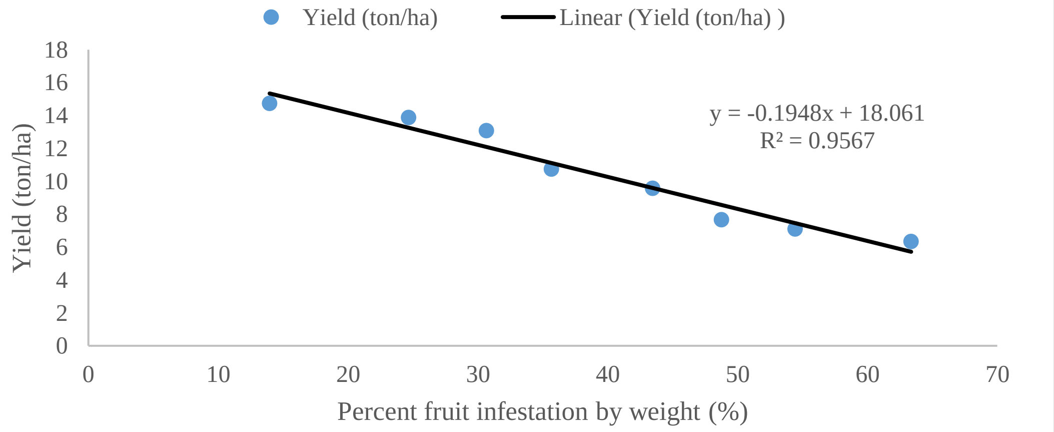


Figure 4.4.2. Relationship between yield (ton/ha) and percent fruit infestation by weight (%) of brinjal caused by BSFB

4.4.7.3. Shoot infestation

Correlation study was done to establish the relationship between the percent shoot infestation and yield (kg/plot) of brinjal during the management of brinjal shoot and fruit borer by different botanicals and other chemical insecticides. From the study it was revealed that, significant correlation was observed between the shoot infestation and yield of brinjal (Figure 4.4.3). It was evident from the Figure 4.4.3 that the regression equation y = -0.2606x + 18.104 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.9752) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a negative relationship between shoot infestation and yield of brinjal, i.e., the yield decreased with the increase of the infestation of shoot by brinjal shoot and fruit borer.

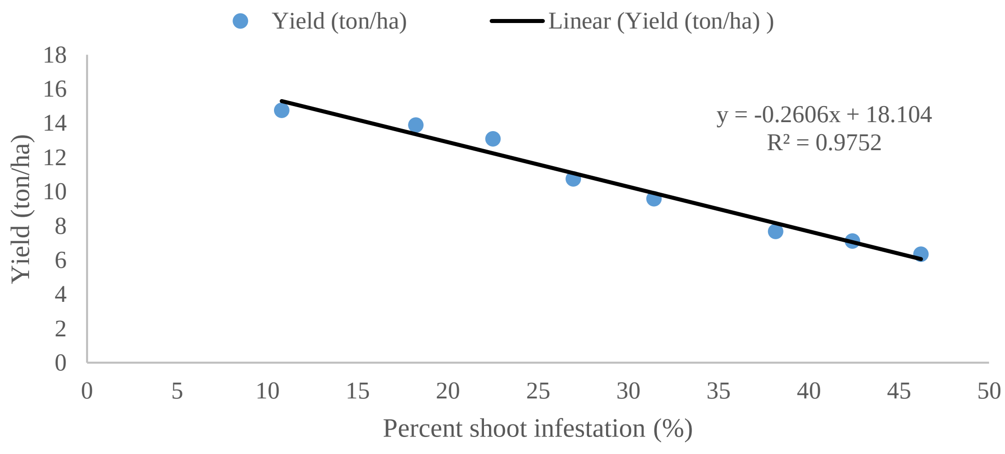


Figure 4.4.3. Relationship between yield (ton/ha) and percent shoot infestation (%) of brinjal caused by BSFB

Experiment-5: Development of IPM packages against BSFB for safe and hazard free brinjal production

This chapter comprises the development of IPM packages against BSFB for safe and hazard free production of brinjal in Bangladesh. The data have been presented and discussed and possible interpretations are made under the following sub-headings:

4.5.1. Shoot infestation

The effect of IPM packages on the percent shoot infestation of brinjal caused by brinjal shoot and fruit borer has been shown in Table 4.5.1. Significant variations were observed among the IPM packages in terms of percent shoot infestation of brinjal caused by brinjal shoot and fruit borer. The lowest percent of shoot infestation (10.85%) was recorded in IPM package P_7, which was statistically different from others, followed by P_9 (18.26), P_6 (23.75) and P_5 (27.11%). On the other hand, the highest percent of shoot infestation (57.36%) was recorded in IPM package P_{10}, which was statistically different from others and followed by P_1 (50.74), P_4 (46.46), P_2 (42.56), P_8 (37.97) and P_3 (31.51%).

Considering the reduction of shoot infestation, the highest reduction of shoot infestation over control was observed (81.08%) in Package 7, followed by Package 9 (68.17), Package 6 (58.59), Package 5 (52.74) and Package 3 (45.07%). Whereas the lowest reduction of shoot infestation over control was observed in Package 1 (11.54%), followed by Package 4 (19.00), Package 2 (25.80) and Package 8 (33.80%) (Table 4.5.2).

From the above findings it was revealed that the lowest shoot infestation (10.85%) was recorded in treatment P_7 comprised of Pheromone Trap + spraying of Neem oil and Marshal 20 EC at alternate 7 days interval. This result is more or less similar with the findings of Das *et al.* (2018), Sharma *et al.* (2009) and Deshmukh *et al.* (2006). As a result, the order of efficacy of management practices in terms of shoot infestation is $P_7 > P_9 > P_6 > P_5 > P_3 > P_8 > P_2 > P_4 > P_1 > P_{10}$.

Table 4.5.1: Effect of different IPM packages on shoot infestation of brinjal caused by brinjal shoot and fruit borer

Treatments	Number of shoots/plants	Number of infested shoots/plants	% Shoot infestation	% Reduction over control
P_1	7.43 h	3.77 bc	50.74 b	11.54
P_2	8.53 fg	3.63 c	42.56 d	25.80
P_3	9.30 e	2.93 e	31.51 f	45.07
P_4	8.33 g	3.87 b	46.46 c	19.00
P_5	9.70 d	2.63 f	27.11 g	52.74
P_6	10.40 c	2.47 f	23.75 h	58.59
P_7	12.63 a	1.37 h	10.85 j	81.08
P_8	8.77 f	3.33 d	37.97 e	33.80
P_9	11.50 b	2.10 g	18.26 i	68.17
P_{10}	7.27 h	4.17 a	57.36 a	0
CV (%)	2.10	3.26	3.32	-
$LSD_{(0.05)}$	0.34	0.17	1.97	-

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT).

Here, P_1 = Package 1; P_2 = Package 2; P_3 = Package; P_4 = Package 4; P_5 = Package 5; P_6 = Package 6; P_7 = Package 7; P_8 = Package 8; P_9 = Package 9; and P_{10} = Package 10]

4.5.2. Fruit infestation (number)

The effect of IPM packages on the percent infestation by number of brinjal has been shown in Table 4.5.2. Significant variations were observed among the IPM packages in terms of percent infestation by number of brinjal. The lowest percent infestation by number (13.76%) was recorded in IPM package P_7, which was statistically different from others, followed by P_9 (23.46), P_6 (25.95) and P_5 (34.02%). On the other hand, the highest percent of fruit infestation by number (86.96%) was recorded in IPM package P_{10}, which was statistically different from others and followed by P_1 (74.02), P_4 (59.82), P_2 (53.28), P_8 (44.45) and P_3 (40.78%).

Considering the reduction of fruit infestation (number), the highest reduction of fruit infestation (number) over control was observed (84.18%) in Package 7, followed by Package 9 (73.02), Package 6 (70.16), Package 5 (60.88) and Package 3 (53.10%). Whereas the lowest reduction of fruit infestation (number) over control was observed in Package 1 (14.88%), followed by Package 4 (31.21), Package 2 (38.73) and Package 8 (48.88%) (Table 4.5.2).

From the above findings it was revealed that the lowest fruit infestation (13.76%) (number) was recorded in treatment P_7 comprised of Pheromone Trap + spraying of Neem oil and Marshal 20 EC at alternate 7 days interval. This result is more or less similar with the findings of Sabry *et al.* (2014), Kodandaram *et al.* (2010) and Deshmukh *et al.* (2006). As a result, the order of efficacy of management practices in terms of fruit infestation (number) is $P_7 > P_9 > P_6 > P_5 > P_3 > P_8 > P_2 > P_4 > P_1 > P_{10}$.

Table 4.5.2: Effect of different IPM packages on fruit infestation by number of brinjal caused by brinjal shoot and fruit borer

Treatments	Number of fruits/plants	Number of infested fruits/plants	% Fruit infestation (number)	% Reduction over control
P_1	33.33 f	24.67 b	74.02 b	14.88
P_2	40.67 d	21.67 c	53.28 d	38.73
P_3	43.33 d	17.67 d	40.78 f	53.10
P_4	37.33 e	22.33 c	59.82 c	31.21
P_5	48.00 c	16.33 e	34.02 g	60.88
P_6	52.67 b	13.67 f	25.95 h	70.16
P_7	63.00 a	8.67 g	13.76 j	84.18
P_8	42.00 d	18.67 d	44.45 e	48.88
P_9	54.00 b	12.67 f	23.46 i	73.02
P_{10}	30.67 f	26.67 a	86.96 a	0
CV (%)	3.96	3.61	6.02	-
$LSD_{(0.05)}$	3.02	1.13	4.71	-

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT).

Here, P_1 = Package 1; P_2 = Package 2; P_3 = Package; P_4 = Package 4; P_5 = Package 5; P_6 = Package 6; P_7 = Package 7; P_8 = Package 8; P_9 = Package 9; and P_{10} = Package 10]

4.5.3. Fruit infestation (weight)

The effect of IPM packages on the percent fruit infestation by weight of brinjal caused by brinjal shoot and fruit borer has been shown in Table 4.5.3. Significant variations were observed among the IPM packages in terms of percent fruit infestation by weight of brinjal. The lowest percent of fruit infestation by weight (14.86%) was recorded in IPM package P_7, which was statistically different from others, followed by P_9 (25.17), P_6 (30.44) and P_5 (35.95%). On the other hand, the highest percent of fruit infestation by weight (87.13%) was recorded in IPM package P_{10}, which was statistically different from others and followed by P_1 (82.75), P_4 (61.76), P_2 (55.24), P_8 (49.15) and P_3 (44.24%).

Considering the reduction of fruit infestation (weight), the highest reduction of fruit infestation (weight) over control was observed (82.95%) in Package 7, followed by Package 9 (71.11), Package 6 (65.06), Package 5 (58.74) and Package 3 (49.23%). Whereas the lowest reduction of fruit infestation (weight) over control was observed in Package 1 (5.03%), followed by Package 4 (29.12), Package 2 (36.60) and Package 8 (43.59%) (Table 4.5.3).

From the above findings it was revealed that the lowest fruit infestation (14.86%) (weight) was recorded in treatment P_7 comprised of Pheromone Trap + spraying of Neem oil and Marshal 20 EC at alternate 7 days interval. This result is more or less similar with the findings of Sabry *et al.* (2014), Dutta *et al.* (2011) and Deshmukh *et al.* (2006). As a result, the order of efficacy of management practices in terms of fruit infestation (weight) is $P_7 > P_9 > P_6 > P_5 > P_3 > P_8 > P_2 > P_4 > P_1 > P_{10}$.

Table 4.5.3: Effect of different IPM packages on fruit infestation by weight of brinjal caused by brinjal shoot and fruit borer

Treatments	Weight of fruit/plant (kg)	Weight of infested fruit/plant (kg)	Weight of healthy fruit/plant (kg)	% Fruit infestation (weight)	% Reduction over control
P_1	2.10 i	1.74 b	0.36 i	82.75 b	5.03
P_2	2.45 g	1.35 d	1.10 g	55.24 d	36.60
P_3	2.66 e	1.18 f	1.48 e	44.24 f	49.23
P_4	2.32 h	1.43 c	0.89 h	61.76 c	29.12
P_5	2.97 d	1.07 g	1.90 d	35.95 g	58.74
P_6	3.11 c	0.95 h	2.16 c	30.44 h	65.06
P_7	3.57 a	0.53 j	3.04 a	14.86 j	82.95
P_8	2.54 f	1.25 e	1.29 f	49.15 e	43.59
P_9	3.34 b	0.84 i	2.50 b	25.17 i	71.11
P_{10}	2.09 i	1.82 a	0.27 j	87.13 a	0
CV (%)	1.50	2.13	3.03	2.68	
$LSD_{(0.05)}$	0.08	0.54	0.08	2.24	

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT).

Here, P_1 = Package 1; P_2 = Package 2; P_3 = Package; P_4 = Package 4; P_5 = Package 5; P_6 = Package 6; P_7 = Package 7; P_8 = Package 8; P_9 = Package 9; and P_{10} = Package 10]

4.5.4. Yield attributing characteristics

Length of healthy fruit: The effect of IPM packages on the length of healthy fruit has been shown in Table 4.5.4. Significant variations were observed among the IPM packages in terms of length of healthy fruit. The highest length of healthy fruit (8.67 cm) was recorded in IPM package P_7, which was statistically different from others, followed by P_9 (8.30), P_6 (8.07) and P_5 (7.94 cm). On the other hand, the lowest length of healthy fruit (6.24 cm) was recorded in IPM package P_{10}, which was statistically different from others, followed by P_1 (6.43), P_4 (6.88), P_2 (7.14), P_8 (7.35) and P_3 (7.53 cm).

Girth of healthy fruit: The effect of IPM packages on the girth of healthy fruit has been shown in Table 4.5.4. Significant variations were observed among the IPM packages in terms of girth of healthy fruit. The highest girth of healthy fruit (22.16 cm) was recorded in IPM package P_7, which was statistically different from others, followed by P_9 (21.86), P_6 (20.16) and P_5 (19.84 cm). On the other hand, the lowest girth of healthy fruit (18.03 cm) was recorded in IPM package P_{10}, which was statistically different from others, followed by P_1 (18.25), P_4 (18.44), P_2 (18.75), P_8 (13.06) and P_3 (13.38 cm).

Length of infested fruit: The effect of IPM packages on the length of infested fruit has been shown in Table 4.5.4. Significant variations were observed among the IPM packages in terms of length of infested fruit. The highest length of infested fruit (5.84 cm) was recorded in IPM package P_7, which was statistically different from others, followed by P_9 (5.24), P_6 (4.92) and P_5 (4.63 cm). On the other hand, the lowest length of infested fruit (3.04 cm) was recorded in IPM package P_{10}, which was statistically different from others, followed by P_1 (3.17), P_4 (3.43), P_2 (3.67), P_8 (4.14) and P_3 (4.25 cm).

Girth of infested fruit: The effect of IPM packages on the girth of infested fruit has been shown in Table 4.5.4. Significant variations were observed among the IPM packages in terms of girth of infested fruit. The highest girth of infested fruit (13.66 cm) was recorded in IPM package P_7, which was statistically similar with P_9 (13.83), P_6 (13.66), P_5 (13.44) and P_3 (13.38 cm). On the other hand, the lowest girth of infested fruit (11.46 cm) was recorded in IPM package P_{10}, which was statistically similar with P_1 (11.74) and P_4 (12.26) and followed by P_2 (12.84) and P_8 (13.06 cm).

From the above findings it was revealed that the highest length and girth of healthy fruit and length and girth of infested fruit (8.67, 22.16, 5.84 and 13.96 cm, respectively) was recorded in treatment P_7 comprised of Pheromone Trap + spraying of Neem oil and Marshal 20 EC at alternate 7 days interval. This result is more or less similar with the findings of Das *et al.* (2014), Dutta *et al.* (2011), and Sharma *et al.* (2009). As a result, the order of efficacy of management practices in terms of length and girth of healthy fruit and length and girth of infested fruit is $P_7 > P_9 > P_6 > P_5 > P_3 > P_8 > P_2 > P_4 > P_1 > P_{10}$.

Table 4.5.4: Effect of different IPM packages on fruit characteristics of brinjal

Treatments	Healthy fruit		Infested fruit	
	Length (cm)	**Girth (cm)**	**Length (cm)**	**Girth (cm)**
P_1	6.43 i	18.25 i	3.17 i	11.74 e
P_2	7.14 g	18.75 g	3.67 g	12.84 cd
P_3	7.53 e	19.56 e	4.25 e	13.38 abc
P_4	6.88 h	18.44 h	3.43 h	12.26 de
P_5	7.94 d	19.84 d	4.63 d	13.44 abc
P_6	8.07 c	20.16 c	4.92 c	13.66 abc
P_7	8.67 a	22.16 a	5.84 a	13.96 a
P_8	7.35 f	19.24 f	4.14 f	13.06 bcd
P_9	8.30 b	21.86 b	5.24 b	13.83 ab
P_{10}	6.24 j	18.03 j	3.04 j	11.46 e
CV (%)	0.63	0.15	0.67	0.20
$LSD_{(0.05)}$	0.08	0.05	0.05	0.77

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT).

Here, P_1 = Package 1; P_2 = Package 2; P_3 = Package; P_4 = Package 4; P_5 = Package 5; P_6 = Package 6; P_7 = Package 7; P_8 = Package 8; P_9 = Package 9; and P_{10} = Package 10]

Number of bores: The effect of IPM packages on the number of bores per fruit has been shown in Table 4.5.5. Significant variations were observed among the IPM packages in terms of number of bores per fruit. The lowest number of bores per fruit (1.33 bores) was recorded in IPM package P_7, which was statistically similar with P_9 (1.67) and P_6 (2.00) and followed by P_5 (2.67). On the other hand, the highest number of bores per fruit (6.33 bores) was recorded in IPM package P_{10}, which was statistically different from others, followed by P_1 (5.33), P_4 (4.67), P_2 (4.00), P_8 (3.67) and P_3 (3.00).

Weight of edible portion of infested fruit: The effect of IPM packages on the weight of edible portion of infested fruit has been shown in Table 4.5.5. Significant variations were observed among the IPM packages in terms of weight of edible portion of infested fruit. The highest weight of edible portion of infested fruit (0.48 kg) was recorded in IPM package P_7, which was statistically similar with P_9 (0.44) and followed by P_6 (0.42) and P_5 (0.39 kg). On the other hand, the lowest weight of edible portion of infested fruit (0.26 kg) was recorded in IPM package P_{10}, which was statistically similar with P_1 (0.28), P_4 (0.31), P_2 (0.31) and followed by P_8 (0.32) and P_3 (0.36 kg).

Weight of non-edible portion of infested fruit: The effect of IPM packages on the weight of non-edible portion of infested fruit has been shown in Table 4.5.5. Significant variations were observed among the IPM packages in terms of weight of non-edible portion of infested fruit. The lowest weight of non-edible portion of infested fruit (0.05 kg) was recorded in IPM package P_7, which was statistically different from others and followed by P_9 (0.40), P_6 (0.52) and P_5 (0.68 kg). On the other hand, the highest weight of non-edible portion of infested fruit (1.57 kg) was recorded in IPM package P_{10}, which was statistically different from others and followed by P_1 (1.46), P_4 (1.12), P_2 (1.04), P_8 (0.92) and P_3 (0.81 kg).

From the above findings it was revealed that the lowest bores per fruit, highest weight of edible and non-edible portion of infested fruit (1.33 bores, 0.48 kg and 0.05 kg, respectively) was recorded in treatment P_7 comprised of Pheromone Trap + spraying of Neem oil and Marshal 20 EC at alternate 7 days interval. This result is more or less similar with the findings of Das *et al.* (2014), Dutta *et al.* (2011) and Sharma *et al.* (2009). As a result, the order of efficacy of management practices in terms of bores per fruit, weight of edible and non-edible portion of infested fruit is $P_7 > P_9 > P_6 > P_5 > P_3 > P_8 > P_2 > P_4 > P_1 > P_{10}$.

Table 4.5.5: Effect of different IPM packages on yield attributing characteristics of brinjal

Treatments	Number of bore/fruit	Edible fruit weight (kg)	Non-edible fruit weight (kg)
P_1	5.33 b	0.28 ef	1.46 b
P_2	4.00 cd	0.31 def	1.04 d
P_3	3.00 ef	0.36 cd	0.81 f
P_4	4.67 bc	0.31 def	1.12 c
P_5	2.67 fg	0.39 bc	0.68 g
P_6	2.00 gh	0.42 b	0.52 h
P_7	1.33 h	0.48 a	0.05 j
P_8	3.67 de	0.32 de	0.92 e
P_9	1.67 h	0.44 ab	0.40 i
P_{10}	6.33 a	0.26 f	1.57 a
CV (%)	14.58	2.64	3.28
$LSD_{(0.05)}$	0.87	0.05	0.05

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT).

Here, P_1 = Package 1; P_2 = Package 2; P_3 = Package; P_4 = Package 4; P_5 = Package 5; P_6 = Package 6; P_7 = Package 7; P_8 = Package 8; P_9 = Package 9; and P_{10} = Package 10]

4.5.5. Yield of brinjal

The effect of IPM packages on the yield of brinjal per plot has been shown in Table 4.5.6. Significant variations were observed among the IPM packages in terms of yield of brinjal per plot. The highest yield of brinjal plot^{-1} (8.77 kg) was recorded in IPM package P_7, which was statistically different from others and followed by P_9 (8.26), P_6 (7.76) and P_5 (6.43 kg). On the other hand, the lowest yield of brinjal plot^{-1} (3.26 kg) was recorded in IPM package P_{10}, which was statistically different from others and followed by P_1 (3.82), P_4 (3.95), P_2 (4.28), P_8 (4.56) and P_3 (5.75 kg).

Considering the increase of brinjal yield, the highest increase of brinjal yield over control was observed (169.02%) in Package 7, followed by Package 9 (153.37), Package 6 (138.04), Package 5 (97.24) and Package 3 (76.38%). Whereas the lowest increase of brinjal yield over control was observed in Package 1 (17.18%), followed by Package 4 (21.17), Package 2 (31.29) and Package 8 (39.88%) (Table 4.5.6).

From the above findings it was revealed that the highest yield of brinjal per plot (8.77 kg) was recorded in treatment P_7 comprised of Pheromone Trap + spraying of Neem oil and Marshal 20 EC at alternate 7 days interval. This result is more or less similar with the findings of Sabry *et al.* (2014), Das *et al.* (2014) and Dutta *et al.* (2011). As a result, the order of efficacy of management practices in terms of yield of brinjal is $P_7 > P_9 > P_6 > P_5 > P_3 > P_8 > P_2 > P_4 > P_1 > P_{10}$.

Table 4.5.6: Effect of different IPM packages on yield of brinjal

Treatments	Yield/plant (kg)	Yield (ton/ha)	% Increase over control
P_1	0.69 f	3.82 i	17.18
P_2	0.77 de	4.28 g	31.29
P_3	0.82 d	5.75 e	76.38
P_4	0.74 ef	3.95 h	21.17
P_5	0.90 c	6.43 d	97.24
P_6	0.95 c	7.76 c	138.04
P_7	1.17 a	8.77 a	169.02
P_8	0.81 d	4.56 f	39.88
P_9	1.09 b	8.26 b	153.37
P_{10}	0.62 g	3.26 j	0
CV (%)	2.03	0.50	-
$LSD_{(0.05)}$	0.05	0.05	-

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT).

Here, P_1 = Package 1; P_2 = Package 2; P_3 = Package; P_4 = Package 4; P_5 = Package 5; P_6 = Package 6; P_7 = Package 7; P_8 = Package 8; P_9 = Package 9; and P_{10} = Package 10]

4.5.6. Beneficial arthropods

Number of lady bird beetle: The effect of IPM packages on the number of lady bird beetle per plot has been shown in Table 4.5.7. Significant variations were observed among the IPM packages in terms of number of lady bird beetle per plot. The highest number of lady bird beetle plot^{-1} (4.67 lady bird beetle) was recorded in IPM package P_{10}, which was statistically similar with P_8 (4.00) and P_3 (3.67) and followed by P_2 (3.33). On the other hand, the lowest number of lady bird beetle plot^{-1} (1.00 lady bird beetle) was recorded in IPM package P_7, which was statistically similar with P_9 (1.33) and P_5 (1.67) and followed by P_6 (2.33), P_1 (2.67) and P_4 (3.00).

Number of ant: The effect of IPM packages on the number of ant per plot has been shown in Table 4.5.7. Significant variations were observed among the IPM packages in terms of number of ant per plot. The highest number of ant plot^{-1} (5.67 ant) was recorded in IPM package P_{10}, which was statistically similar with P_8 (5.33) and followed by P_3 (4.67), P_2 (4.00). On the other hand, the lowest number of ant plot^{-1} (1.00 ant) was recorded in IPM package P_7, which was statistically similar with P_9 (1.33) and followed by P_5 (2.00), P_6 (2.67), P_1 (3.00) and P_4 (3.67).

Number of field spider: The effect of IPM packages on the number of field spider per plot has been shown in Table 4.5.7. Significant variations were observed among the IPM packages in terms of number of field spider per plot. The highest number of field spider plot^{-1} (3.67 field spider) was recorded in IPM package P_{10}, which was statistically similar with P_8 (3.67) and P_3 (3.33) and followed by P_2 (2.67). On the other hand, the lowest number of field spider plot^{-1} (1.33 field spider) was recorded in IPM package P_7, which was statistically similar with P_5 (1.67) and P_6 (1.67) and followed by P_1 (2.00), P_4 (2.33) and P_9 (2.67).

From the above findings it was revealed that the number lady bird beetle, ant and field spider per plot (4.67 lady bird beetle, 5.67 ant and 3.67 field spider, respectively) was recorded in treatment P_7 comprised of Pheromone Trap + spraying of Neem oil and Marshal 20 EC at alternate 7 days interval. This result is more or less similar with the findings of Dutta *et al.* (2011), Kodandaram *et al.* (2010) and Deshmukh *et al.* (2006). As a result, the order of efficacy of management practices in terms of number lady bird beetle, ant and field spider per plot is $P_7 > P_9 > P_5 > P_1 > P_6 > P_4 > P_2 > P_3 > P_8 > P_{10}$.

Table 4.5.7: Effect of different IPM packages on beneficial arthropods of brinjal

Treatments	Number of lady bird beetle	Number of ant	Number of field spider
P_1	2.67 cde	3.00 d	2.00 cde
P_2	3.33 bcd	4.00 c	2.67 bc
P_3	3.67 abc	4.67 b	3.33 ab
P_4	3.00 bcd	3.67 c	2.33 cd
P_5	1.67 efg	2.00 e	1.67 def
P_6	2.33 def	2.67 d	1.67 def
P_7	1.00 g	1.00 f	1.33 f
P_8	4.00 ab	5.33 a	3.67 a
P_9	1.33 fg	1.33 f	2.67 bc
P_{10}	4.67 a	5.67 a	3.67 a
CV (%)	20.52	10.80	17.69
$LSD_{(0.05)}$	0.97	0.62	0.71

[In a column, means followed by the same letter(s) are not significantly different at 5% level of probability by Duncan's Multiple Range Test (DMRT).

Here, P_1 = Package 1; P_2 = Package 2; P_3 = Package; P_4 = Package 4; P_5 = Package 5; P_6 = Package 6; P_7 = Package 7; P_8 = Package 8; P_9 = Package 9; and P_{10} = Package 10]

4.5.7. Relationship between fruit infestation and yield of brinjal

4.5.7.1. Fruit infestation by number

Correlation study was done to establish the relationship between the percent fruit infestation (number) and yield (kg/plot) of brinjal during the management of brinjal shoot and fruit borer by different IPM packages. From the study it was revealed that, significant correlation was observed between the fruit infestation and yield of brinjal (Figure 4.5.1). It was evident from the Figure 4.5.1 that the regression equation $y = -0.0813x + 9.3942$ gave a good fit to the data, and the co-efficient of determination ($R^2 = 0.8709$) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a negative relationship between fruit infestation (number) and yield of brinjal, i.e., the yield decreased with the increase of the infestation of fruit (number) by brinjal shoot and fruit borer.

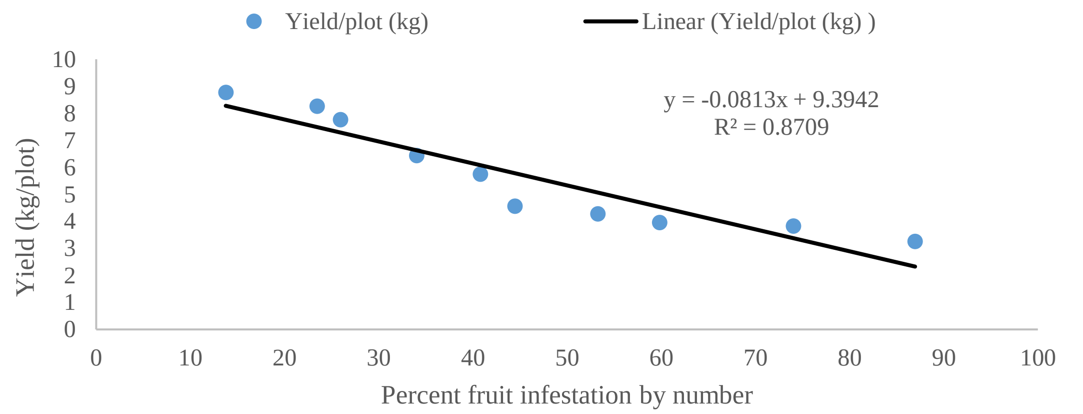


Figure 4.5.1. Relationship between percent fruit infestation by number and yield per plot of brinjal

4.5.7.2. Shoot infestation

Correlation study was done to establish the relationship between the percent shoot infestation and yield (kg/plot) of brinjal during the management of brinjal shoot and fruit borer by different IPM packages. From the study it was revealed that, significant correlation was observed between the shoot infestation and yield of brinjal (Figure 4.5.2). It was evident from the Figure 4.5.2 that the regression equation $y = -0.1317x + 10.248$ gave a good fit to the data, and the co-efficient of determination ($R^2 = 0.9511$) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a negative relationship between shoot infestation and yield of brinjal, i.e., the yield decreased with the increase of the infestation of shoot by brinjal shoot and fruit borer.

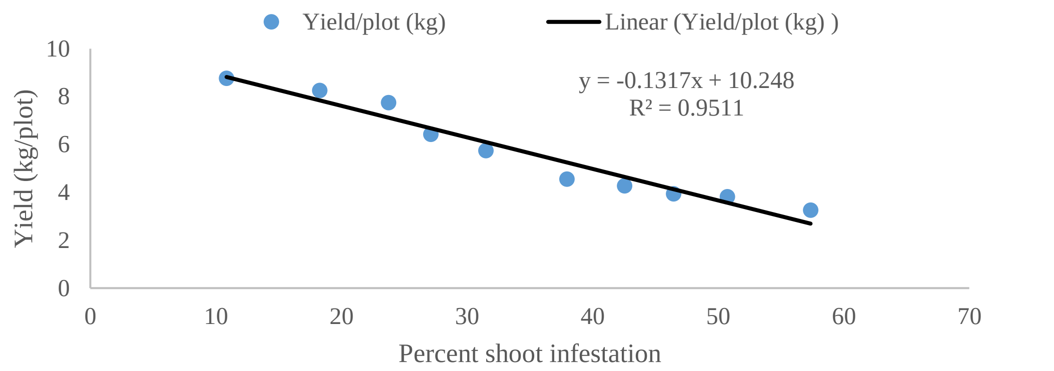


Figure 4.5.2. Relationship between percent shoot infestation and yield per plot of brinjal

4.5.7.3. Fruit infestation by weight

Correlation study was done to establish the relationship between the percent fruit infestation (weight) and yield (kg/plot) of brinjal during the management of brinjal shoot and fruit borer by different IPM packages. From the study it was revealed that, significant correlation was observed between the fruit infestation (weight) and yield of brinjal (Figure 4.5.3). It was evident from the Figure 4.5.3 that the regression equation y = -0.0793x + 9.5444 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.8701) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a negative relationship between fruit infestation (weight) and yield of brinjal, i.e., the yield decreased with the increase of the infestation of fruit (weight) by brinjal shoot and fruit borer.

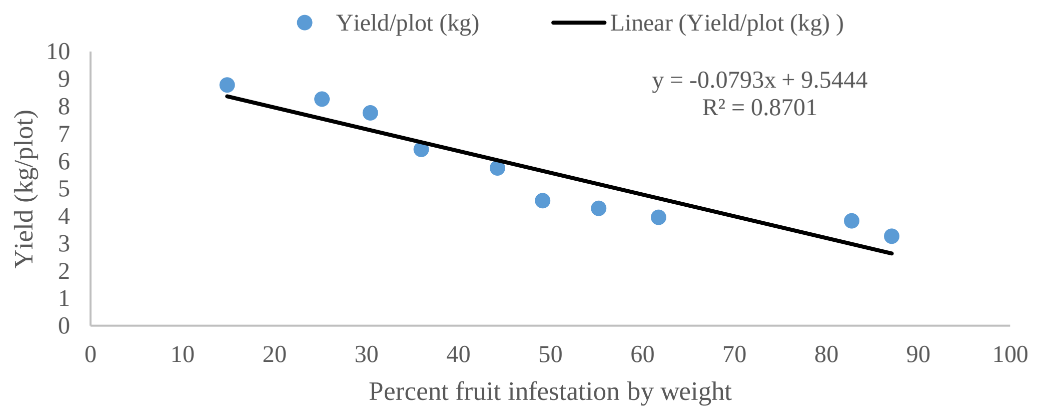


Figure 4.5.3. Relationship between percent fruit infestation by weight and yield per plot of brinjal

CHAPTER V
SUMMARY AND CONCLUSION

The experiments were conducted in the Entomology experimental field of Sher-e-Bangla Agricultural University (SAU), Sher-e-Banglanagar, Dhaka, Bangladesh, during 2016 to 2020 to evaluate cross cutting issues, varietal performance, efficiency of different pharomome traps and different level of trap settings and develop an IPM pcakages against brinjal shoot and fruit borer.

A field survey was conducted to assess the cross-cutting issues of farmers' practices for the management of brinjal shoot and fruit borer (BSFB) in Bangladesh with the participation of 310 brinjal farmers. Among 310 brinjal farmers participated in the survey, 92.6% farmers were male and 7.4% were female. Among the farmers who participated in the survey study, the highest 41.6 percent farmers were under 36 to 45 age group followed by 35.8 percent under 26 to 35 age group. The educational level of maximum 29.67% farmers were up to primary level, 28.67% up to class eight, 16.67% farmers completed SSC, 8.00% completed HSC and 2.33% completed bachelor degree. Conversely, 14.6% farmers had no literacy knowledge.

The farmers participated in the survey reported that they cultivated different types of crops, where one farmer usually cultivated more than one crops in their land. As per their response, out of 310, all (100%) farmers cultivated both brinjal and cereal crops in their field, which was closely followed by cultivation of other vegetables (90.00%). While the average land size under brinjal cultivation was 26.3 decimal that was ranged from 2.5 to 80 decimal.

The survey findings revealed that, maximum 59.33 farmers cultivated hybrid varieties of brinjal in their field followed by 55.67% farmers cultivated Uttara variety (BARI brinjal-1), 42.0% mentioned Singnath variety, 35 percent famers mentioned Ishwardi (BARI brinjal-6) variety, 31.67 percent farmers cultivated Islampuri variety, 22.33 percent mentioned Khatiya variety, 17 percent farmers mentioned Tarapuri (BARI brinjal-2) variety, 15.33 percent mentioned local variety and others.

All farmers under the survey conformed that brinjal shoot and fruit borer infestation occurred in their brinjal field. They also informed that larval stage of brinjal shoot and fruit borer was the destructive phase for brinjal. Among the respondents about 74.8% farmers reported that adult moths of BSFB was found active at morning in their brinjal field. On the other hand, maximum 44.8 percent farmers informed that winter season was the most favorable season for brinjal shoot and fruit borer infestation.

Out of 310 farmers, about 70 percent reported that the tender shoots of brinjal plant were more vulnerable to brinjal shoot and fruit borer infestation, while 90 percent mentioned that the tender fruits were most vulnerable to the BSFB infestation. Among the respondents, maximum 83 percent reported that BSFB damaged about 11 to 25 percent shoots. In case of fruit damage, maximum 54 percent reported that BSFB damaged about 26 to 50 percent fruits.

All the brinjal farmers participated in the survey informed that they applied chemical insecticides for the management of brinjal shoot and fruit borer followed by other treatments. Among them 57.4 percent reported that they applied mixture of insecticides against BSFB. To another question of how many numbers of insecticides they mixed for a mixture to apply at a time, they replied that on an average 2.57 insecticides they mixed for a mixture that was ranged from 2 to 3 insecticides. While, maximum 45% of them applied insecticides three days interval in their brinjal field. In case of Jashore area, highest proportion (9.7%) of farmers applied insecticides two days interval, in Dhaka area, highest proportion (12.9%) of farmers applied insecticides three days interval, in Narshingdi area, highest proportion (9%) of farmers applied insecticides three days interval, and in Cumilla and Munshiganj districts, more or less similar trends of results were observed like Narshingdi in terms of frequency of insecticide application through a cropping season of brinjal aiming to control the brinjal shoot and fruit borer infestation.

Maximum 72.3 percent farmers usually obtained information about the management of brinjal shoot and fruit borer from the Pesticide dealer.

While about 84 percnet of respondents were well known about the hazardous effect of insecticides on the environment. Out of 310 sample farmers, about 77.0 percent farmers informed that the spraying of insecticides polluted water as most hazardous effect.

Out of 310 sample farmers, 87.4 percent of them reported that they were well known about the hazard free management of BSFB. Among them, 62.3 were well known about the pheromone trap as hazard free management of BSFB. Out of 148 farmers, about 66.0 percent farmers reported that they obtained pheromone lures from pesticide dealer. The farmers who used pheromone trap, about 82 percent of them obtained expected result by using pheromone trap in their brinjal field. Out of 27 farmers who didn't get desire result, about 48 percent of them reported that they didn't get desired result as because of water used in the trap became dry.

To find out the susseptable variety a field experiment was conducted to screeing of brinjal varieties for resistance/tolerance against brinjal shoot and fruit borer. V_{13} (BARI Hybrid Begun-4) and V_8 (BARI Begun-6) performed as the most susceptible brinjal varieties in terms of percent shoot infestation (29.78 and 26.80%, respectively), whereas the V_1 (BARI Bt Begun-1) performed as the least susceptible varieties in terms of shoot infestation (3.37%) due to attack of brinjal shoot and fruit borer. As a result, the trends of least preferable brinjal varieties in terms of percent shoot infestation is V_1 (BARI Bt Begun-1) > V_4 (BARI Bt Begun-4) > V_2 (BARI Bt Begun-2) > V_3 (BARI Bt Begun-3) > V_5 (BARI Begun-1 (Uttara)) > V_6 (BARI Begun-4 (Kajla)) > V_{10} (BARI Begun-8) > V_{12} (BARI Begun-10 (Bholanath)) > V_9 (BARI Begun-7 (Singnath)) > V_7 (BARI Begun-5 (Nayantara)) > V_{11} (BARI Begun-9 (Dohazari)) > V_8 (BARI Begun-6 (Ishurdi local)) > V_{13} (BARI Hybrid Begun-4).

V_{13} (BARI Hybrid Begun-4) performed as the most suitable brinjal varieties in terms of percent fruit infestation by number (35.32%), whereas the V_1 (BARI Bt Begun-1) performed as the least suitable varieties in terms of fruit infestation by number (3.77%) due to attack of brinjal shoot and fruit borer. As a result, the trends of least preferable brinjal varieties in terms of percent fruit infestation by number is V_1 (BARI Bt Brinjal-1) > V_4 (BARI Bt Brinjal-4) > V_3 (BARI Bt Brinjal-3) > V_2 (BARI Bt Brinjal-2) > V_5 (BARI Begun-1 (Uttara)) > V_7 (BARI Begun-5 (Nayantara)) > V_{12} (BARI Begun-10 (Bholanath)) > V_{10} (BARI Begun-8) > V_6 (BARI Begun-4 (Kajla)) > V_8 (BARI Begun-6 (Ishurdi local)) > V_{11} (BARI Begun-9 (Dohazari)) > V_9 (BARI Begun-7 (Singnath)) > V_{13} (BARI Hybrid Begun-4).

V_{13} (BARI Hybrid Begun-4) performed as the most suitable brinjal varieties in terms of percent fruit infestation by weight (47.52%), whereas the V_1 (BARI Bt Begun-1) performed as the least suitable varieties in terms of fruit infestation by weight (4.57%) due to attack of brinjal shoot and fruit borer. As a result, the trends of least preferable brinjal varieties in terms of percent fruit infestation by weight is V_1 (BARI Bt Brinjal-1) > V_3 (BARI Bt Brinjal-3) > V_4 (BARI Bt Brinjal-4) > V_2 (BARI Bt Brinjal-2) > V_5 (BARI Begun-1 (Uttara)) > V_{10} (BARI Begun-8) > V_6 (BARI Begun-4 (Kajla)) > V_9 (BARI Begun-7 (Singnath)) > V_8 (BARI Begun-6 (Ishurdi local)) > V_7 (BARI Begun-5 (Nayantara)) > V_{12} (BARI Begun-10 (Bholanath)) > V_{11} (BARI Begun-9 (Dohazari)) > V_{13} (BARI Hybrid Begun-4).

The least preferred (resistant) brinjal varieties such as V_1 (BARI Bt Begun-1) manifested low infestation intensity on fruits and the most preferred (susceptible) brinjal varieties such as V_{13} (BARI Hybrid Begun-4) evident high infestation intensity on fruits was found in scale 1, scale 2 and scale 3 infestation. Similar results were also reported by several researchers. Islam (2014) found that BARI brinjal 6 manifested low infestation intensity (scale 1) on fruits and the most preferred (susceptible) brinjal varieties such as BARI brinjal 7 evident high infestation intensity (scale 3) on fruits.

V_{13} was mostly preferred by BSFB produced the highest number of branches and leaves per plant, while the least preferred brinjal variety V_1 produced the lowest number of branches and leaves per plant. Earlier, it was observed that variety V_1 (BARI Bt Begun-1) which possessed lowest number of infestations in terms shoot infestation, fruit infestation by number and weight produced the lowest number of branches and leaves per plant. It was also inferred from these findings that the bushy and shady varieties of brinjal manifested by higher number of branches and leaves werer much preferred by the brinjal shoot and fruit borer for infestation on shoots and fruits.

In case of number of fruits per plant the following trend was found: V_2 (BARI Bt Begun-2)> V_1 (BARI Bt Begun-1)> V_{13} (BARI Hybrid Begun-4)> V_7 (BARI Begun-5 (Nayantara))> V_5 (BARI Begun-1 (Uttara)) > V_3 (BARI Bt Begun-3) > V_4 (BARI Bt Begun-4) > V_{10} (BARI Begun-8) > V_{12} (BARI Begun-10 (Bholanath)) > V_9 (BARI Begun-7 (Singnath)) > V_{11} (BARI Begun-9 (Dohazari)) > V_8 (BARI Begun-6 (Ishurdi local)) > V_6 (BARI Begun-4 (Kajla)).

In case of fruit length (cm), it was found the following trend: V_{12} (BARI Begun-10 (Bholanath)) > V_9 (BARI Begun-7 (Singnath)) > V_{10} (BARI Begun-8) > V_5 (BARI Begun-1 (Uttara)) > V_6 (BARI Begun-4 (Kajla)) > V_1 (BARI Bt Begun-1) > V_4 (BARI Bt Begun-4) > V_2 (BARI Bt Begun-2) > V_{11} (BARI Begun-9 (Dohazari)) > V_3 (BARI

Bt Begun-3) > V_{13} (BARI Hybrid Begun-4) > V_8 (BARI Begun-6 (Ishurdi local)) > V_7 (BARI Begun-5 (Nayantara)).

In case of single fruit girth (cm), it was found the following trend: V_7 (BARI Begun-5 (Nayantara)) > V_8 (BARI Begun-6 (Ishurdi local)) > V_4 (BARI Bt Begun-4) > V_{11} (BARI Begun-9 (Dohazari)) > V_3 (BARI Bt Begun-3) > V_{13} (BARI Hybrid Begun-4) > V_5 (BARI Begun-1 (Uttara)) > V_2 (BARI Bt Bregun-2) > V_1 (BARI Bt Begun-1) >V_{12} (BARI Begun-10 (Bholanath)) > V_6 (BARI Begun-4 (Kajla)) > V_{10} (BARI Begun-8) > V_9 (BARI Begun-7 (Singnath)).

In case of single fruit weight (g), it was found the following trend V_3 (BARI Bt Begun-3) > V_7 (BARI Begun-5 (Nayantara)) > V_{13} (BARI Hybrid Begun-4) > V_8 (BARI Begun-6 (Ishurdi local)) > V_4 (BARI Bt Begun-4) > V_1 (BARI Bt Begun-1) > V_5 (BARI Begun-1 (Uttara)) > V_9 (BARI Begun-7 (Singnath)) > V_{10} (BARI Begun-8) > V_2 (BARI Bt Begun-2) > V_6 (BARI Begun-4 (Kajla)) > V_{11} (BARI Begun-9 (Dohazari)) > V_{12} (BARI Begun-10 (Bholanath)).

In terms of increasing the yield of brinjal is V_{13} (BARI Hybrid Begun-4) > V_5 (BARI Begun-1 (Uttara)) > V_1 (BARI Bt Brinjal-1) > V_3 (BARI Bt Brinjal-3) > V_2 (BARI Bt Brinjal-2) > V_7 (BARI Begun-5 (Nayantara)) > V_4 (BARI Bt Brinjal-4) > V_{10} (BARI Begun-8) > V_8 (BARI Begun-6 (Ishurdi local)) > V_9 (BARI Begun-7 (Singnath)) > V_{12} (BARI Begun-10 (Bholanath)) > V_6 (BARI Begun-4 (Kajla)) > V_{11} (BARI Begun-9 (Dohazari)).

V_{13} (BARI Hybrid Begun 4) performed as the most suitable brinjal varieties in terms of percent moisture content of leaves (88.20%), whereas the V_5 (BARI Begun-1) performed as the least suitable varieties in terms of moisture percent (83.53%) of leaves. As a result, the of least preferable brinjal varieties in terms of percent moisture content is V_{13} (BARI Hybrid Begun-4) > V_{10} (BARI Begun-8) > V_6 (BARI Begun-4 (Kajla)) > V_{11} (BARI Begun-9 (Dohazari)) > V_2 (BARI Bt Brinjal-2) > V_{12} (BARI Begun-10 (Bholanath)) > V_4 (BARI Bt Begun-4) > V_1 (BARI Bt Begun-1) > V_9 (BARI Begun-7 (Singnath)) > V_7 (BARI Begun-5 (Nayantara)) > V_3 (BARI Bt Begun-3) > V_8 (BARI Begun-6 (Ishurdi local)) > V_5 (BARI Begun-1 (Uttara)).

V_8 (BARI Begun-6) performed as the best suitable brinjal varieties in terms of trichome hair density per cm^2 (24.00 trichome/cm^2), whereas the V_9 (BARI Begun-7) performed as the least suitable varieties in terms of trichome hair density per cm^2 (8.26 trichome/cm^2). As a result, the order of trends of the most preferable brinjal varieties in terms of trichome hair density per cm^2 is V_8 (BARI Begun-6 (Ishurdi local)) > V_4 (BARI Bt Begun-4) > V_7 (BARI Begun-5 (Nayantara)) > V_3 (BARI Bt Begun-3) > V_{13} (BARI Hybrid Begun-4) > V_5 (BARI Begun-1 (Uttara)) > V_1 (BARI Bt Begun-1) > V_{12} (BARI Begun-10 (Bholanath)) > V_{11} (BARI Begun-9 (Dohazari)) > V_2 (BARI Bt Begun-2) > V_6 (BARI Begun-4 (Kajla)) > V_{10} (BARI Begun-8) > V_9 (BARI Begun-7 (Singnath)).

V_5 (BARI Begun 1) possessed the highest number of thorn density per top fully open first leaf and per 10 cm of apical stem (4.33 and 6.47) respectively while the least amount of thorn density per top fully open first leaf and per 10 cm of apical stem was recorded in terms of V_{13} (BARI Hybrid Begun 4) (0.13 and 1.56, respectively).

Evaluating the efficiency of pheromone traps and traping methods for capturing adult moth of *Leucinodes orbonalis* in brinjal field a field study was conducted in the experimental field.

The BARI Trap II performed the best results in terms of showing lowest shoot infestation in brinjal field than that of other two types of pheromone traps. The pheromone traps setting at different heights significantly influenced the shoot infestation by BSFB. The Pheromone Trap set at canopy level performed the best results in terms of showing lowest shoot infestation in brinjal field than that of other two setting positions of the pheromone traps. The BARI Trap II showed the best performance in causing lowest shoot infestation (10.0 percent) when it was set at canopy level in the brinjal field rather than other types of pheromone traps and any other setting positions.

The BARI Trap II performed the best results in terms of lowest fruit infestation by both number and weight than that of other two types of pheromone traps. The Pheromone Trap set at canopy level performed the best results in terms of producing lowest fruit infestation by both number and weight of brinjal than that of other two setting positions of the pheromone traps. The BARI Trap II showed the best performance in causing lowest fruit infestation (8.08 and 9.44 percent, respectivly) by both number and weight when it was set at canopy level in the brinjal field rather than other types of pheromone traps and any other setting positions.

The BARI Trap II performed the best results in terms of production of fruit yield than that of other two types of pheromone traps. The Pheromone Trap set at canopy level performed the best results in terms of producing highest brinjal fruit yield. The BARI Trap II showed the best performance in producing highest fruit yield when it was set at canopy level in the brinjal field rather than other types of pheromone traps and any other setting positions.

To evaluate the effectiveness of botanicals and other non-chemical approaches against BSFB in comparison with chemical insecticides a study was done in the field and found the bellow observations:

The lowest shoot infestation (10.79%) (number), lowest fruit infestation (13.91%) (number) and lowest fruit infestation (13.96%) (weight) was recorded in treatment T_6 comprised of Spraying of Marshal 20 EC (Carbosulfan) @ 3.0 ml/L of water at alternate 7 days interval. As a result, the order of efficacy of management practices is $T_6>T_4>T_1>T_7>T_2>T_5>T_3>T_8$.

The highest length of healthy fruit, girth of healthy fruit, length of infested fruit and girth of infested fruit (8.72 cm, 21.75 cm, 5.85 cm and 14.02 cm, respectively) was recorded in treatment T_6 comprised of Spraying of Marshal 20 EC (Carbosulfan) @ 3.0 ml/L of water at alternate 7 days interval. As a result, the order of efficacy of management practices in terms of length of healthy fruit, girth of healthy fruit, length of infested fruit and girth of infested fruit is $T_6>T_4>T_1>T_7>T_2>T_5>T_3>T_8$.

The lowest number of bores fruit^{-1}, highest weight of edible portion of infested fruit and lowest weight of non-edible portion of infested fruit (2.67 bores, 3.00 g/fruit and 0.39 g/fruit, respectively) were recorded in treatment T_6 comprised of Spraying of Marshal 20 EC (Carbosulfan) @ 3.0 ml/L of water at alternate 7 days interval. As a result, the order of efficacy of management practices in terms of number of bores fruit^{-1}, weight of edible portion of infested fruit and weight of non-edible portion of infested fruit is $T_6>T_4>T_1>T_7>T_2>T_5>T_3>T_8$.

The highest yield of brinjal (8.84 kg/plot) as recorded in treatment T_6 comprised of Spraying of Marshal 20 EC (Carbosulfan) @ 3.0 ml/L of water at alternate 7 days interval. As a result, the order of efficacy of management practices in terms of yield of brinjal is $T_6>T_4>T_1>T_7>T_2>T_5>T_3>T_8$.

The highest number of lady bird beetle, ant, trichogamma, honey bee and spider (4.67 lady bird beetle, 5.67 ant, 2.67 trichogamma, 3.33 honey bee and 4.33 spider, respectively) was recorded in treatment T_1 comprised of spraying of Neem oil @ 3.0 ml/L of water at 7 days interval. As a result, the order of efficacy of management practices in terms of number of lady bird beetle, ant, trichogamma, honey bee and spider is $T_1>T_2>T_4>T_5>T_3>T_8>T_7>T_6$.

For developing of IPM packages against BSFB for safe and hazard free production of brinjal in Bangladesh a field study was done in the experimental field and the observations were:

The lowest shoot infestation (10.85%), lowest fruit infestation (13.76%) (number), lowest fruit infestation (14.86%) (weight) was recorded in treatment P_7 comprised of Pheromone Trap located at the canopy level @ 1 lure at 30 days interval + Spraying of Neem oil (Azadirachtin) @ 3.0 ml/L and Marshal 20 EC (Carbosulfan) @ 3.0 ml/L of water at alternate 7 days interval, respectively. As a result, the order of efficacy of management practices in terms of fruit infestation (number) is $P_7> P_9> P_6> P_5> P_3> P_8> P_2> P_4 > P_1> P_{10}$.

The highest length and girth of healthy fruit and length and girth of infested fruit (8.67 cm, 22.16 cm, 5.84 cm and 13.96 cm, respectively) was recorded in treatment P_7 comprised of Pheromone Trap located at the canopy level @ 1 lure at 30 days interval + Spraying of Neem oil (Azadirachtin) @ 3.0 ml/L and Marshal 20 EC (Carbosulfan) @ 3.0 ml/L of water at alternate 7 days interval, respectively. As a result, the order of efficacy of management practices in terms of length and girth of healthy fruit and length and girth of infested fruit is $P_7> P_9> P_6> P_5> P_3> P_8> P_2> P_4 > P_1> P_{10}$.

The lowest bores per fruit, highest weight of edible, non-edible portion of infested fruit and fruit yield per plot (1.33 bores, 0.48 kg and 0.05 kg, 8.77 kg respectively) was recorded in treatment P_7 comprised of Pheromone Trap located at the canopy level @ 1 lure at 30 days interval + Spraying of Neem oil (Azadirachtin) @ 3.0 ml/L and Marshal 20 EC (Carbosulfan) @ 3.0 ml/L of water at alternate 7 days interval, respectively. As a result, the order of efficacy of management practices in terms of bores per fruit, weight of edible and non-edible portion of infested fruit is $P_7> P_9> P_6> P_5> P_3> P_8> P_2> P_4 > P_1> P_{10}$.

The number lady bird beetle, ant, trichgamma, honey bee and field spider per plot (4.67 lady bird beetle, 5.67 ant, 3.67 trichogamma, 3.67 honey bee and 3.67 field spider, respectively) was recorded in treatment P_7 comprised of Pheromone Trap located at the canopy level @ 1 lure at 30 days interval + Spraying of Neem oil (Azadirachtin) @ 3.0 ml/L and Marshal 20 EC (Carbosulfan) @ 3.0 ml/L of water at alternate 7 days interval, respectivelyAs a result, the order of efficacy of management practices in terms of number lady bird beetle, ant, trichgamma, honey bee and field spider per plot is $P_9 > P_8 > P_3 > P_2 > P_4 > P_1 > P_6 > P_5 > P_7 > P_{10}$.

Conclusion

From this study it can be concluded that, brinjal shoot and fruit borer is the most destructive insect pest of brinjal. Brinjal growing farmers of Bangladesh also well known about BSFB and the nature of damage of BSFB. They usually used insecticides indiscriminately against BSFB in their brinjal field. Now a days, they also practice pheromone traps and other botanical pesticides against BSFB as an eco-friendly management practice. But they didn't get appropriate results due to lack of proper knowledge about the uses of pheromone traps. Considering this point, varietal screening was done to get resistant brinjal variety (BARI Begun 1) against BSFB. Apart from it, BARI trap II performed best amongst all traps which was set at the same level of the canopy of the brinjal. BARI trap II at canopy level captured highest number of BSFB and reduces the fruit and shoot infestation. From another experiment, Marshal 20 EC (Carbosulfan) @ 3.0 ml/L of water at alternate 7 days interval showed the best performance to reduce the fruit and shoot infestation as well as increase the yield of brinjal compared with different chemical and botanical insecticides against BSFB. So, keep in the mind about the environmental issues, another experiment was conducted to get proper IPM package to control BSFB. From this experiment it can be revealed that, IPM package 7 comprised of Pheromone Trap located at the canopy level @ 1 lure at 30 days interval + Spraying of Neem oil (Azadirachtin) @ 3.0 ml/L and Marshal 20 EC (Carbosulfan) @ 3.0 ml/L of water at alternate 7 days interval, respectively showed the best performance to reduce the infestation of BSFB as well as increase the yield of brinjal.

CHAPTER VI

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APPENDICES

Appendix I: Distribution of brinjal shoot and fruit borer

List of the origin and distribution of the brinjal shoot and fruit borer

Continent/Country/Region	**Reference**
Africa	
Burundi	EPPO (2022); UK, CAB International (1976)
Cameroon	EPPO (2022); UK, CAB International (1976); Stephan *et al.* (2016)
Congo, Democratic Republic of the	Mally *et al.* (2015); UK, CAB International (1976)
Congo, Republic of the	EPPO (2022)
Côte d'Ivoire	Obodji *et al.* (2015)
Ethiopia	EPPO (2022); UK, CAB International (1976)
Ghana	EPPO (2022)
Kenya	EPPO (2022); UK, CAB International (1976)
Lesotho	EPPO (2022); UK, CAB International (1976)
Malawi	EPPO (2022)
Mozambique	EPPO (2022); UK, CAB International (1976)
Nigeria	EPPO (2022); UK, CAB International (1976); Harriman and Nwammadu (2016); Emeasor and Uwalaka (2018)
Rwanda	EPPO (2022); UK, CAB International (1976)
São Tomé and Príncipe	EPPO (2022)
Sierra Leone	EPPO (2022) UK, CAB International (1976)
Somalia	EPPO (2022); UK, CAB International (1976)
South Africa	EPPO (2022); UK, CAB International (1976)
Tanzania	EPPO (2022); UK, CAB International (1976)
Uganda	EPPO (2022); UK, CAB International (1976)
Zambia	EPPO (2022)
Zimbabwe	EPPO (2022)
Asia	
Bangladesh	UK, CAB International (1976); Rashid *et al.* (2008); Latif *et al.* (2009); Latif *et al.* (2010); Prodhan *et al.* (2018); EPPO (2022)
Brunei	UK, CAB International (1976); Waterhouse (1993); EPPO (2022)
Cambodia	Waterhouse (1993); EPPO (2022)
China	EPPO (2022); Zhang *et al.* (2010)
Hong Kong	UK, CAB International (1976); EPPO (2022)
India	EPPO (2022); Naresh *et al.* (1986); Patel *et al.* (1988);Chang JianCheng *et al.* (2016); Sandip Patra *et al.* (2016)
Indonesia	EPPO (2022)
Japan	EPPO (2022); Tamaki and Miyara (1982)
Laos	Waterhouse (1993); Chang JianCheng *et al.* (2016); EPPO (2022)
Malaysia	EPPO (2022); Ismail *et al.* (2010)

Continent/Country/Region	Reference
Myanmar	Waterhouse (1993); EPPO (2022)
Nepal	UK, CAB International (1976); Chang JianCheng *et al.* (2016); Sandip Patra *et al.* (2016)
Pakistan	UK, CAB International (1976); Anwar *et al.* (2015); Qudsia Yousafi *et al.* (2015); Humayun Javed *et al.* (2017); Sajjad Anwar *et al.* (2017); EPPO (2022)
Philippines	EPPO (2022); Chang JianCheng *et al.* (2016)
Saudi Arabia	CABI (Undated); EPPO (2022)
Singapore	UK, CAB International (1976); Waterhouse (1993); EPPO (2022)
Sri Lanka	UK, CAB International (1976); EPPO (2022)
Taiwan	UK, CAB International (1976); Chang JianCheng *et al.* (2016); EPPO (2022)
Thailand	UK, CAB International (1976); Waterhouse (1993); Chang JianCheng *et al.* (2016); EPPO (2022)
United Arab Emirates	EPPO (2022)
Vietnam	UK, CAB International (1976); Waterhouse (1993); Chang JianCheng *et al.* (2016); EPPO (2022)
Europe	
Belgium	Seebens *et al.* (2017)
Denmark	EPPO (2022)
Netherlands	NPPO of the Netherlands (2013); EPPO (2022)
United Kingdom	Higgott (2009)
Oceania	
Australia	EPPO (2022)

পরিশিষ্ট ২ঃ বেগুন চাষীদের জন্যে জরিপ প্রশ্নাবলী

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Cross cutting issues of insecticides and other chemicals used for the management of brinjal shoot and fruit borer (BSFB) in Bangladesh

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সেট-১: বেগুন চাষীদের জন্যে জরিপ প্রশ্নাবলী

কোডঃ				

মোবাইল ফোন											

A.0 বেগুন চাষীর ব্যক্তিগত তথ্যাদিঃ

A.1 উত্তরদাতার নাম: ---।

A.2 গ্রাম ---।

A.3 কৃষি ব্লক: ---।

A.4 উপজেলা: ---।

A.5 জেলা: --।

A.6 শিক্ষাগত যোগ্যতা: --------------------------------------।

A.7 বয়স: --।

A.8 পেশাগত: [কোড: ১=ক্ষুদ্র চাষী, ২=মাঝারী চাষী, ৩=বড় চাষী] ☐

A.9 লিঙ্গ: [কোড: ১=পুরুষ, ২=মহিলা] ☐

B.0 বেগুনের আবাদ সংক্রান্ত তথ্যাবলিঃ

B.1 উত্তরদাতার ব্যবহৃত জমির ধরণ/ প্রকৃতি:

বেগুন চাষে ব্যবহৃত জমির ধরণ	**জমির পরিমাণ (শতাংশ)**
১. ফসল চাষে মোট জমির পরিমাণ কত?	
২. এ বছর বেগুন চাষ করেছেন এমন জমির পরিমান বলুন?	
৩. কত বৎসর যাবৎ বেগুন চাষ করছেন?	
৪. বেগুন ছাড়া আপনি আর কি কি ফসল চাষ করেন? [কোড: ১=শস্য, ২=সবজি, ৩=ফল, ৪=পাট, ৫=অন্যান্য..........(উল্লেখ করুন)	

B.2 **আপনি সাধারণতঃ কোন কোন জাতের বেগুন চাষ করেন? একাধিক উত্তর করা যাবে।**

[কোডঃ ১=উত্তরা (বারি বেগুন-১), ২=তারাপুরি (বারি বেগুন-২), ৩=বারি বেগুন-৩, ৪=কাজলা (বারি বেগুন-৪), ৫=নয়নতারা (বারি বেগুন-৫), ৬=বারি বেগুন-৬, ৭=বারি বেগুন-৭, ৮=বারি বেগুন-৮, ৯=বারি বেগুন-৯, ১০=বারি বেগুন-১০, ১১=ইসলামপুরী, ১২=খটখটিয়া, ১৩= লাফফা, ১৪= ঈশ্বরদী-১, ১৫=তাল বা তল্লা বেগুন, ১৬=কেজি বেগুন, ১৭=শিংনাথ, ১৮=ঝুমকো, ১৮=ডিম বেগুন, ১৯=মুক্তকেশী, ২০=শুকতারা, ২১=বিজয়, ২২=হাইব্রিড জাত, ২৩=স্থানীয় জাত, ২৪=বিটি বেগুন, ২৫=অন্যান্য --------, ২৬=অজানা জাত]

B.3 ক. বেগুন চাষের মাধ্যমে বিঘা প্রতি আয় কত? ---------------------- টাকা।

খ. বেগুন চাষে আপনার বিঘা প্রতি লাভ কত?-----------------------টাকা।

B.5 **আপনি সাধারণতঃ কোন কোন উৎস থেকে বেগুনের বীজ/চারা সংগ্রহ করেন?**

উৎসসমূহ	**উত্তরের ধরণ** **(কোডঃ হ্যাঁ=১, না=২)।**	**উৎস অনুযায়ী বীজ/চারার গুনগত মান কেমন?** [কোডঃ ১=ভালো, ২=মাধ্যম, ৩=ভালো নয়]
১. নিজের তৈরী বীজ/চারা		
২. প্রতিবেশী কৃষকের কাছ থেকে সংগৃহীত		
৩. বিএডিসি-এর বীজ/চারা		
৪. অন্য কোন কোম্পানীর বীজ/চারা		
৫. স্থানীয় বাজার/নার্সারি হতে সংগৃহীত বীজ/চারা		
৬. কৃষি গবেষনা প্রতিষ্ঠান হতে সংগৃহীত বীজ/চারা		
৭. অন্যান্য কোন উৎস -------------(যদি থাকে)		

B.7. ক. আপনার বেগুনের জমিতে আপনি কি বেগুনের ডগা ও ফল ছিদ্রকারী পোকাটিকে দেখেছেন? (কোডঃ হ্যাঁ=১, না=২)। ☐

খ. যদি উত্তর হ্যাঁ হয়, তাহলে পোকার কোন অবস্থাটি সবচেয়ে বেশি ক্ষতিকর? (কোডঃ ১=লার্ভা, ২=পিউপা, ৩=পুর্ণাঙ্গ পোকা ☐

B.8. ক. দিনের কোন সময়ে সাধারণত এই পোকাটি বেশি দেখা যায়? (কোডঃ ১=সকালে, ২=দুপুরে, ৩=বিকালে, ৪=রাতে) ☐

খ. বছরের কোন ঋতুতে এই পোকার আক্রমণ বেশি হয়ে থাকে? (কোডঃ ১=গ্রীষ্ম, ২=বর্ষা, ৩=শীত, ৪=হেমন্ত, ৫=শীত; ৬=বসন্ত) ☐

গ. বেগুনের ডগা ও ফল ছিদ্রকারী পোকাটি কি ডগায় আক্রমণ আক্রমণ করে? (কোডঃ হ্যাঁ=১, না=২)। ☐

ঘ. ডগায় আক্রমণের তীব্রতা কেমন? (কোডঃ ১=,১০%, ২=১১-২৫%, ৩=২৬-৫০%, ৪=৫১-৭৫%, ৫-৭৬-১০০%)

ঙ. বেগুনের ডগা ও ফল ছিদ্রকারী পোকাটি কি ফলে আক্রমণ আক্রমণ করে? (কোডঃ হ্যাঁ=১, না=২)। ☐

চ. ফলে আক্রমণের তীব্রতা কেমন? (কোডঃ ১=,১০%, ২=১১-২৫%, ৩=২৬-৫০%, ৪=৫১-৭৫%, ৫-৭৬-১০০%)

B.9. আপনি সাধারণত কিভাবে বেগুনের ডগা ও ফল ছিদ্রকারী পোকার আক্রমণ দমন করেন? নিচের খালিঘরে কোড নাম্বার লিখুনঃ (একাধিক উত্তর গ্রহণযোগ্য)

(কোডঃ ১= গাছে কীটনাশক স্প্রে করে, ২=আলোর ফাঁদ ব্যবহার করে , ৩= ফেরোমন ফাঁদ ব্যবহার করে, ৪= সমন্বিত বালাই পদ্ধতি (আই.পি.এম.), ৫= সেচ প্রদান করে, ৬= ক্ষতিকর পোকাসমূহ হাত দিয়ে সংগ্রহ করে মেরে ফেলা, ৭= সুষম সার ব্যবহার করে, ৮= অন্যান্য -------------------(দয়া করে উল্লেখ করুন)]

B.10. ক. বেগুনের ডগা ও ফল ছিদ্রকারী পোকার আক্রমণ দমনে আপনি সাধারণত কি কি কীটনাশক স্প্রে করেন?

১। ----------------------------------, ২। ---------------------------------, ৩। -------------------------------।

খ. পোকার আক্রমণ দমনে সাধারণত কয়দিন পর পর কীটনাশক স্প্রে করে থাকেন? (কোড: ১=প্রতিদিন ২বার, ২=প্রতিদিন একবার, ৩=একদিন পর পর, ৪=দুইদিন পর পর, ৫= তিন দিন পর পর, ৬=৭দিন পর পর, ৭=এক সপ্তাহের অধিক সময় পর পর)

গ. বেগুনের ডগা ও ফল ছিদ্রকারী পোকার আক্রমণ দমণে কি ধরনের কীটনাশক ব্যবহার করতে হবে এবং কয়দিন পর পর ব্যবহার করতে হবে এই তথ্য আপনি কোথা থেকে পান? (কোড: ১=প্রতিবেশিকে অনুসরণ করে, ২=পূর্ববর্তী অভিজ্ঞতা থেকে, ৩=নিজের ইচ্ছা মত, ৪=কীটনাশক ডিলারের কাছ থেকে, ৫=উপ-সহকারী কৃষি কর্মকর্তা, ৬=উপজেলা কৃষি সম্প্রসারণ কর্মকর্তা, ৭=উপজেলা কৃষি কর্মকর্তা, ৮=বিভিন্ন কীটনাশক কোম্পানীর কাছ থেকে, ৯=ইন্টারনেট ব্যবহার করে, ১০=রেডিও/টেলিভিশন থেকে, ১১= অন্যান্য উৎস থেকে...........................(উল্লেখ করুণ)।

ঘ) আপনি কি বেগুনের ডগা ও ফল ছিদ্রকারী পোকার আক্রমণ দমনে একসাথে একের অধিক কীটনাশক মিশিয়ে ব্যবহার করেছেন?

(কোড: হ্যাঁ=১, না=২)।

ঙ) হ্যাঁ হলে, কতগুলো কীটনাশক একসাথে মিশিয়ে ব্যবহার করেছেন? --------------------

চ) আপনি কি মনে করেন কীটনাশক ব্যবহারের কারণে আপনার বেগুন উৎপাদন বৃদ্ধি পায়? (কোড: হ্যাঁ=১, না=২)।

ছ) হ্যাঁ হলে কতটুকু বৃদ্ধি পায়? (কোড: ১=,১০%, ২=১১-২৫%, ৩=২৬-৫০%, ৪=৫১-৭৫%, ৫-৭৬-১০০%)

B.11. ক. মাত্রারিক্ত কীটনাশক ব্যবহারের কারনে পরিবেশের উপর প্রভাব সম্পর্কে আপনি অবগত আছেন কি?
(কোড: হ্যাঁ=১, না=২)।

খ. যদি উত্তর হ্যাঁ হয়, তবে কোন কোন বিষয়ে অবগত আছেন:

১। ----------------------------------, ২। ---------------------------------, ৩। ------------------------------।

B.12. ক. আপনি কি বেগুনের ডগা ও ফল ছিদ্রকারী পোকার দমনে ফেরোমোন ফাঁদ ব্যবহার সম্পর্কে অবগত আছেন? (কোড: হ্যাঁ=১, ২=না=)।

খ. যদি হ্যাঁ হয়, আপনি কি কখনও নিজের জমিতে বেগুনের ডগা ও ফল ছিদ্রকারী পোকা দমনে ফেরোমোন ফাঁদ ব্যবহার করেছেন? (কোড: হ্যাঁ=১, না=২)

গ. যদি হ্যাঁ হয়, তবে কোথা থেকে আপনি ফেরোমোন ফাঁদ ব্যবহার সম্পর্কে জেনেছেন? (কোড: ১=প্রতিবেশির কাছ থেকে, ২=কীটনাশক ডিলারের কাছ থেকে, ৩=উপ-সহকারী কৃষি কর্মকর্তা, ৪=উপজেলা কৃষি সম্প্রসারণ কর্মকর্তা, ৫=উপজেলা কৃষি কর্মকর্তা, ৬=বিভিন্ন কীটনাশক কোম্পানীর কাছ থেকে, ৭=ইন্টারনেট ব্যবহার করে, ৮=রেডিও/টেলিভিশন থেকে, ৯= অন্যান্য উৎস থেকে...........................(উল্লেখ করুণ)

ঘ. ফেরোমোন ফাঁদে ব্যবহারকৃত লিয়ুর আপনি কোথা থেকে সংগ্রহ করেন? (কোড: ১=প্রতিবেশির কাছ থেকে, ২=কীটনাশক ডিলারের কাছ থেকে, ৩=কৃষি অফিস থেকে, ৪=বিভিন্ন কীটনাশক কোম্পানীর কাছ থেকে, ৫= অন্যান্য উৎস থেকে...........................(উল্লেখ করুণ)

B.13. ক. ফেরোমোন ফাঁদ ব্যবহারের মাধ্যমে উক্ত পোকা দমনে কাঙ্খিত ফল পেয়েছেন কি? (কোড: হ্যাঁ=১, না=২)

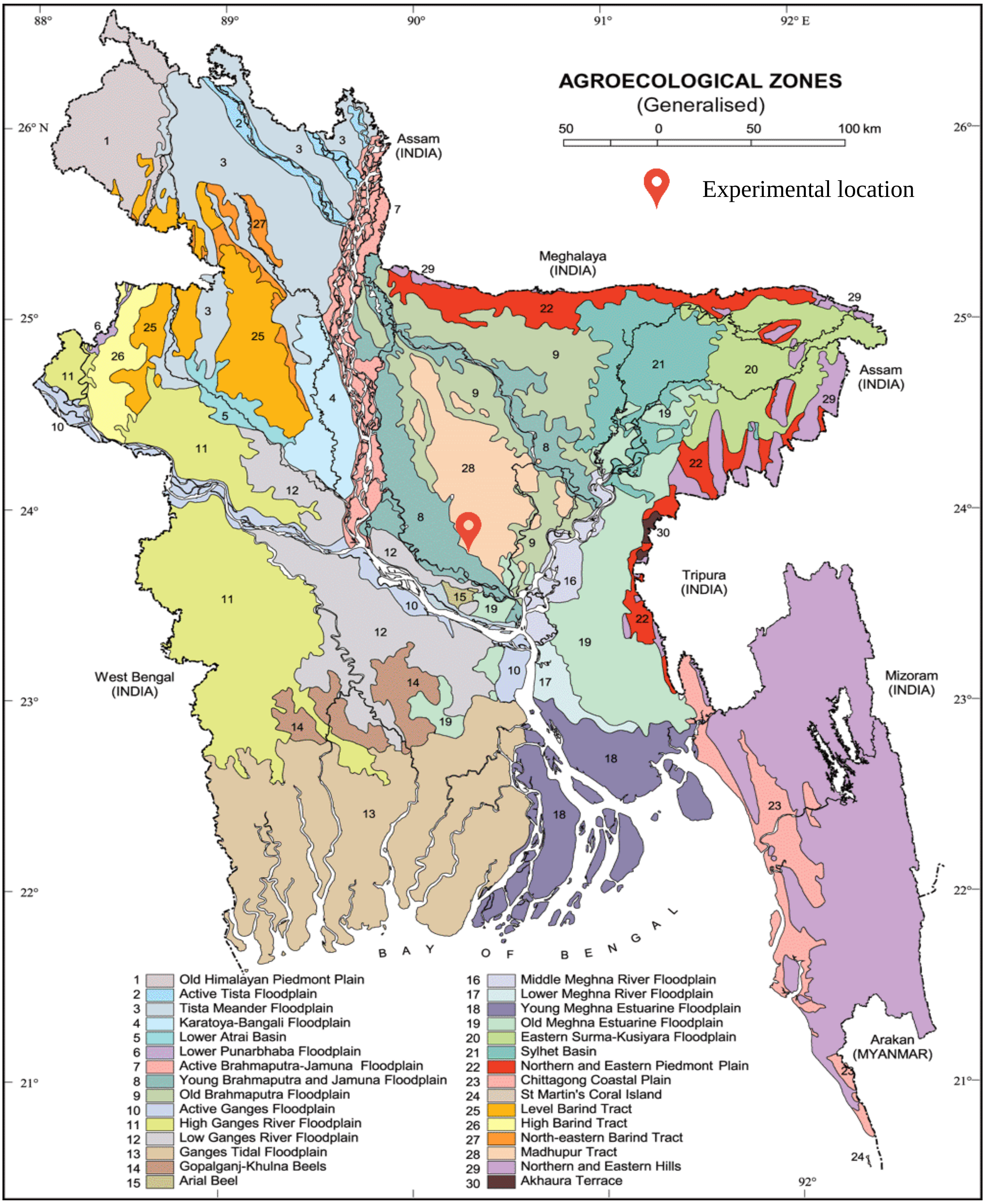
খ. না পেলে তার কারণ কি?

১। ----------------------------------, ২। ---------------------------------, ৩। --------------------------- ।

B.14. বেগুনের ডগা ও ফল ছিদ্রকারী পোকার নিরাপদ দমন ব্যবস্থাপনা সম্পর্কে আপনার সুচিন্তিত মতামত প্রদান করুনঃ

তথ্য সংগ্রহকারীর নামঃ স্বাক্ষর ও তারিখঃ

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



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

Constituents	Percent
Sand	26
Silt	45
Clay	29
Textural class	Silty clay

Chemical composition:

Soil characters	Value
Organic carbon (%)	0.45
Organic matter (%)	0.54
Total nitrogen (%)	0.027
Phosphorus	6.3 µg/g soil
Sulphur	8.42 µg/g soil
Magnesium	1.17 meq/100 g soil
Boron	0.88 µg/g soil
Copper	1.64 µg/g soil
Zinc	1.54 µg/g soil
Potassium	0.10 meg/100g soil

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

Appendix V. Weather information (average temperature, rainfall and relative humidity)

Average temperature (°C)

Year	Month	Day																														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
2017	Oct.	27.4	28.7	29.6	30.5	30.7	29.6	28.2	28.1	27.2	29.4	30.3	30.4	30.2	29.9	29.1	29.7	30.3	29.3	26.5	24.4	24.2	24.6	27.6	27.1	26.5	26.4	26.1	25.1	25.5	21.9	23.5
2017	Nov.	25.2	25.6	25.7	27.2	27	27.1	27	26	25.2	25.4	25.4	26.6	27.1	26.3	23.6	22.8	25.5	26.8	25.7	25.1	24	22.8	22.8	23	22.6	22.6	23.1	21.7	21.6	21.3	
2017	Dec.	21.8	22.2	21.8	21.3	21.1	22.7	22.7	22.8	21	22.1	22.8	23.4	22.9	22	20.7	19.7	20.5	20.5	18	19.1	20.3	20.5	21	21.3	21.5	21.4	21.1	19.4	19.7	21.6	21.6
2018	Jan.	20.6	20.2	18.4	15.7	16.1	16.8	14.1	13	16.6	16.3	13.8	15.1	15.7	14.6	15.7	17.7	18.8	20.1	20	18.3	19	17.7	19.8	19.6	20.5	19.6	17.1	17.1	17.6	18.2	19.1
2018	Feb.	19.1	19.6	20.1	22.4	22.2	21.7	22.2	21.9	23.1	23.6	22.2	23.3	23.9	23	22.3	22.4	21.8	22.5	23.6	24.5	24.8	25	26.1	25.8	27.3	23.4	25.3	25.8			
2018	Mar.	25.9	26.7	27.4	28.2	28.1	27.4	26.2	25.9	25.6	25.5	26.3	27.5	26.5	27.6	28.4	27.3	27.5	28.1	27.8	27.1	28.4	28.1	28.4	29	29.6	27.2	27.6	28.9	28.8	25.1	24.2
2018	Apr.	27.5	26.1	28.6	27.6	27.7	26.5	26.7	25.8	28.3	28.6	26.9	27	28.4	26.5	28.7	29.7	25	27.8	27.2	28.6	26.6	28	29.6	30.2	27.5	26.8	26.7	29.2	22.3	22.7	
2018	May	27.4	25.2	26.7	25.9	26.9	29.4	27.2	29.6	27.8	24.4	25.8	27.5	26.9	27.7	28.5	23.8	27.7	25.8	27.9	26.9	26.3	28.1	26.7	28.7	28.9	30.7	31.3	30.6	29.9	30.6	26.1

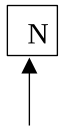
Rainfall (mm)

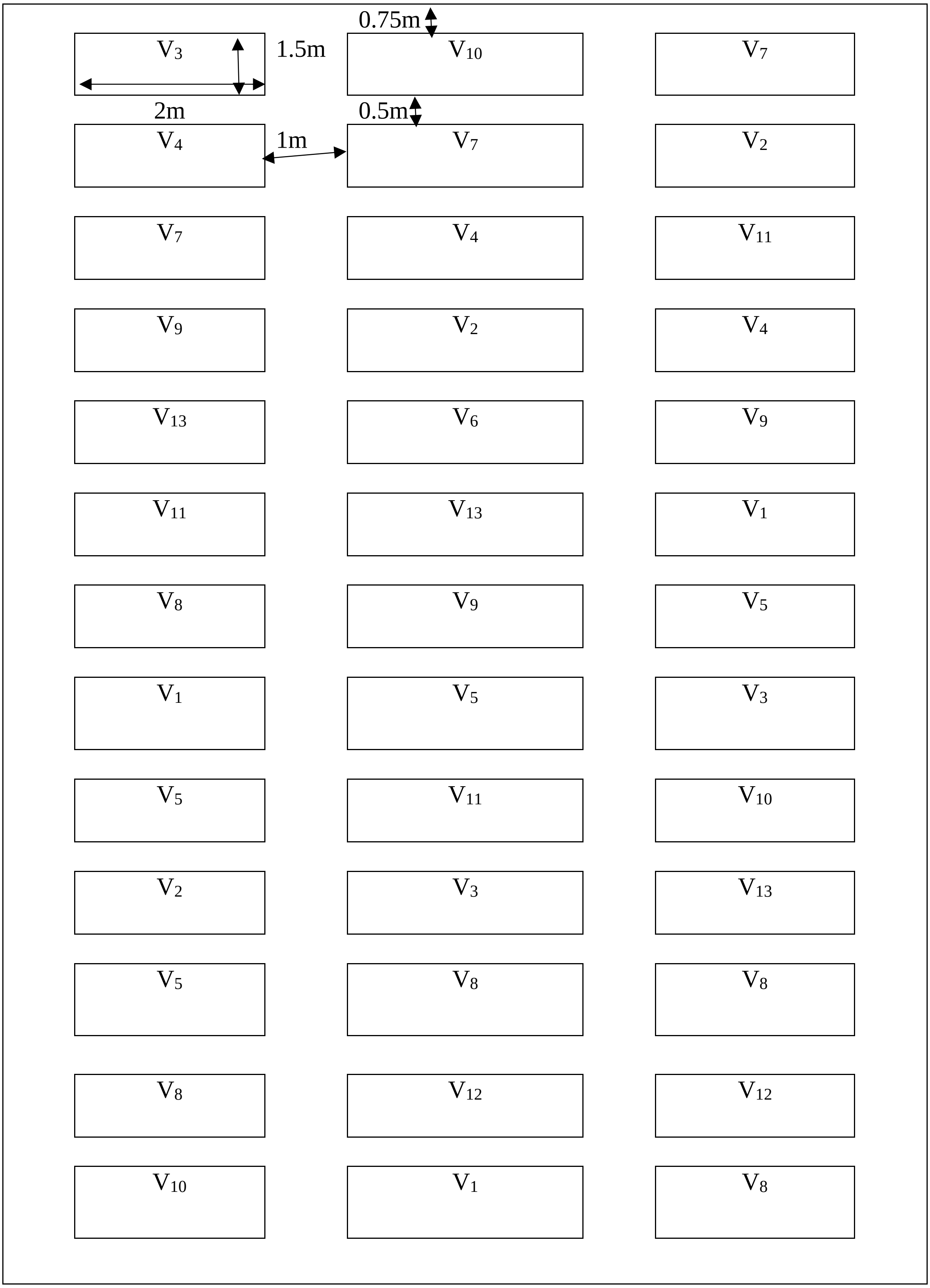
Year	Month	Day																														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
2017	Oct.	31	25	0	0	0	0	5	2	1	0	0	0	0	0	61	0	0	0	0	50	149	86	0	0	2	0	0	0	0	0	0
2017	Nov.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	2	0	0	0	0	0	0	0	0	0	0	0	0	0	
2017	Dec.	0	0	0	0	0	0	0	0	4	15	14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	Jan.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	Feb.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	16	0			
2018	Mar.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	1
2018	Apr.	14	0	0	0	0	0	2	5	0	0	0	8	5	0	42	0	0	50	12	2	17	12	5	0	0	26	32	0	0	77	
2018	May	32	0	5	0	19	10	4	0	0	14	15	2	0	0	0	22	10	0	31	35	35	19	12	52	1	18	0	0	0	0	0

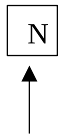
Rainfall (mm)

Year	Month	Day																														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
2017	Oct.	91	81	79	79	73	80	81	79	84	76	73	75	73	75	83	76	76	76	89	96	94	86	79	79	85	80	72	75	70	84	77
2017	Nov.	73	72	70	69	69	68	64	67	71	67	65	59	55	65	77	86	82	78	76	71	54	51	59	61	57	61	66	68	81	70	
2017	Dec.	72	72	67	71	70	68	68	69	95	95	92	81	84	74	64	69	84	79	91	88	79	82	74	71	75	70	72	85	83	67	64
2018	Jan.	71	74	54	72	82	58	67	75	64	68	83	81	83	90	83	70	75	63	58	62	66	78	67	62	58	53	64	62	66	62	67
2018	Feb.	69	79	82	71	82	69	60	50	57	49	38	46	49	59	50	51	62	62	57	57	64	60	64	71	60	73	72	60			
2018	Mar.	60	59	66	66	53	46	39	45	53	45	45	62	65	71	67	65	56	60	60	44	48	60	68	68	64	67	72	68	68	74	69
2018	Apr.	55	66	58	62	61	71	71	75	65	61	70	63	66	76	65	61	76	70	75	72	86	80	76	73	66	64	69	64	86	87	
2018	May	74	80	74	82	81	76	81	81	84	84	77	71	77	74	74	83	79	87	83	83	90	89	90	83	82	78	73	70	62	65	87

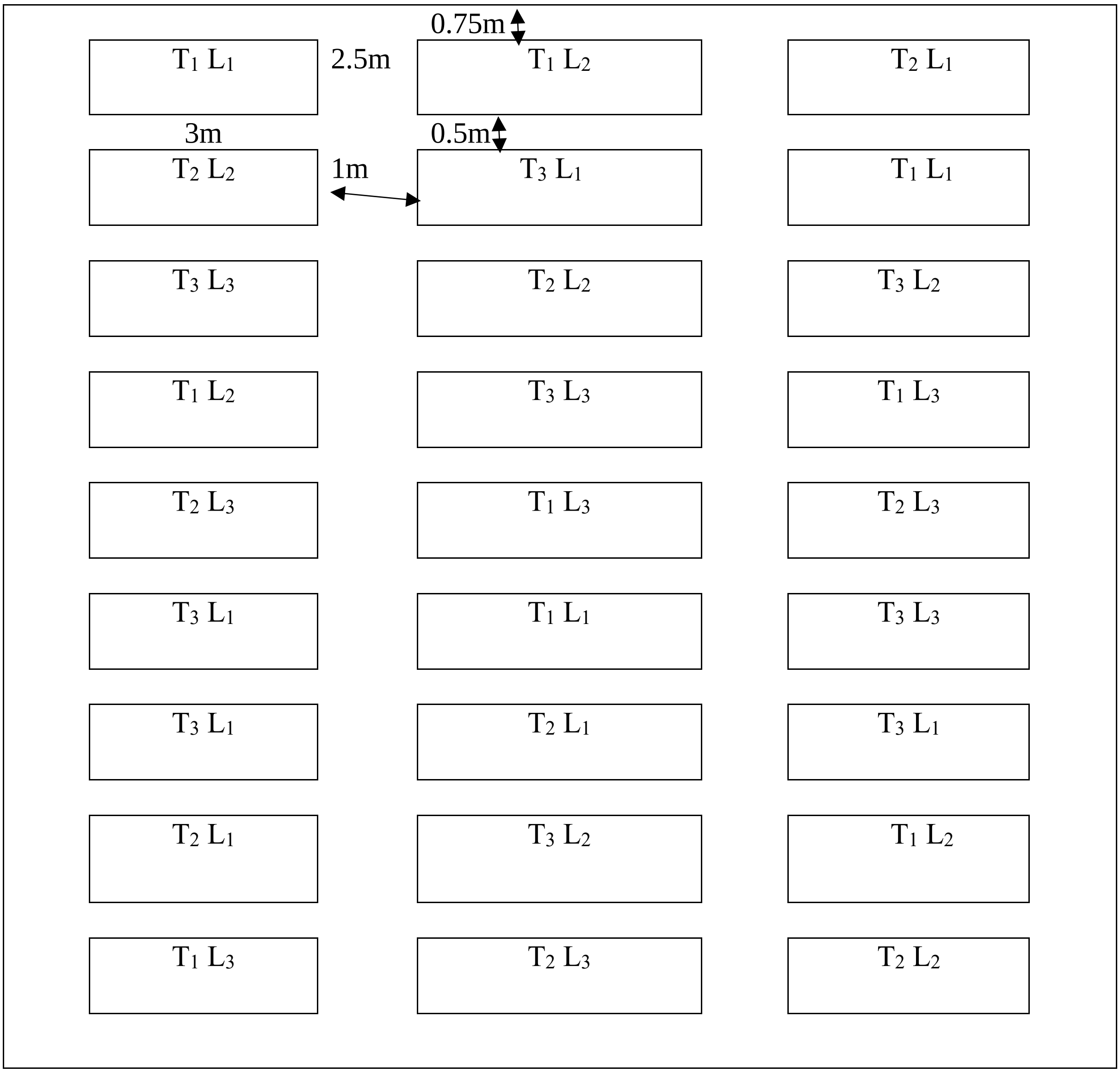
Appendix VI: Field layout for experiment 2



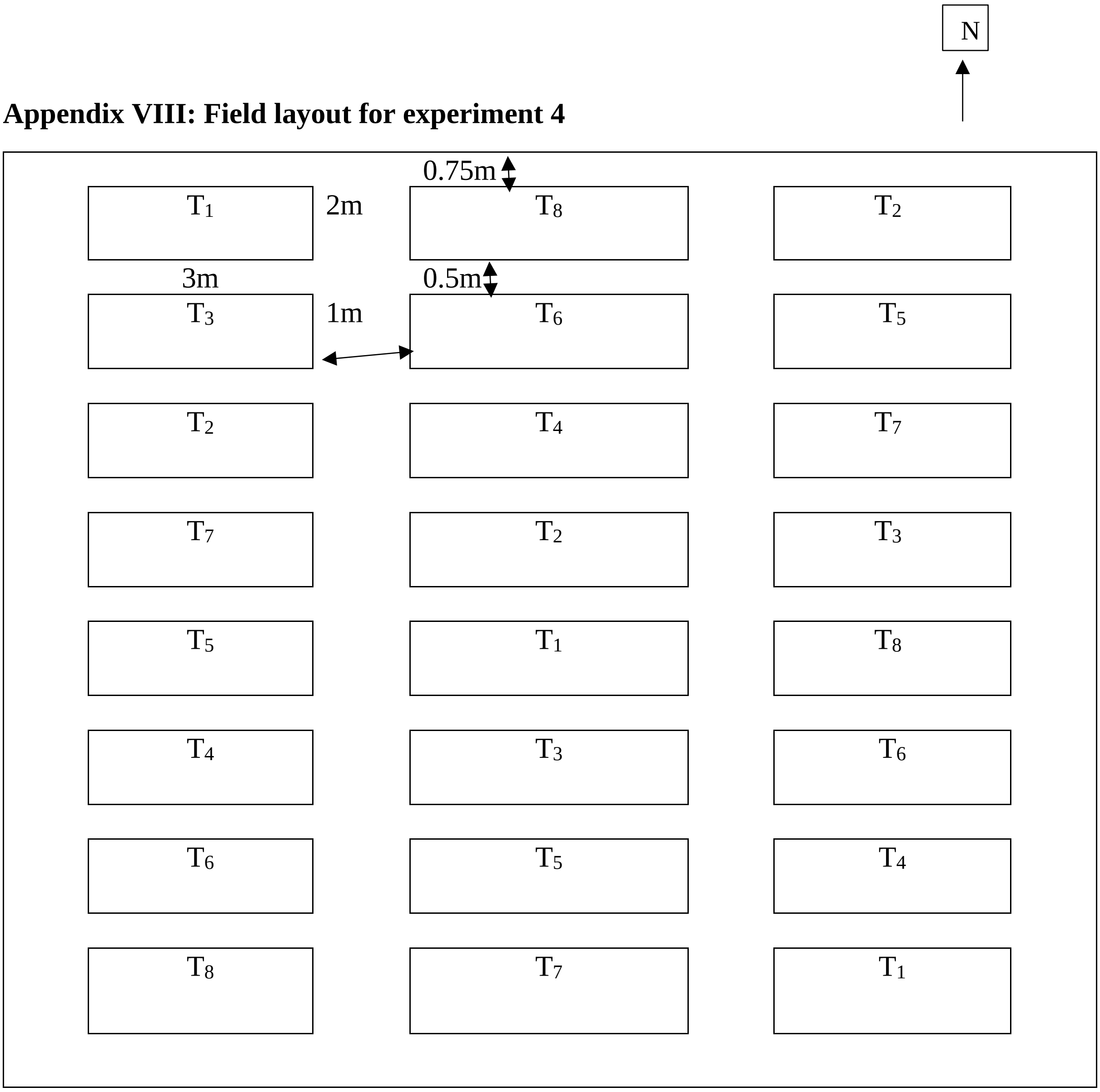




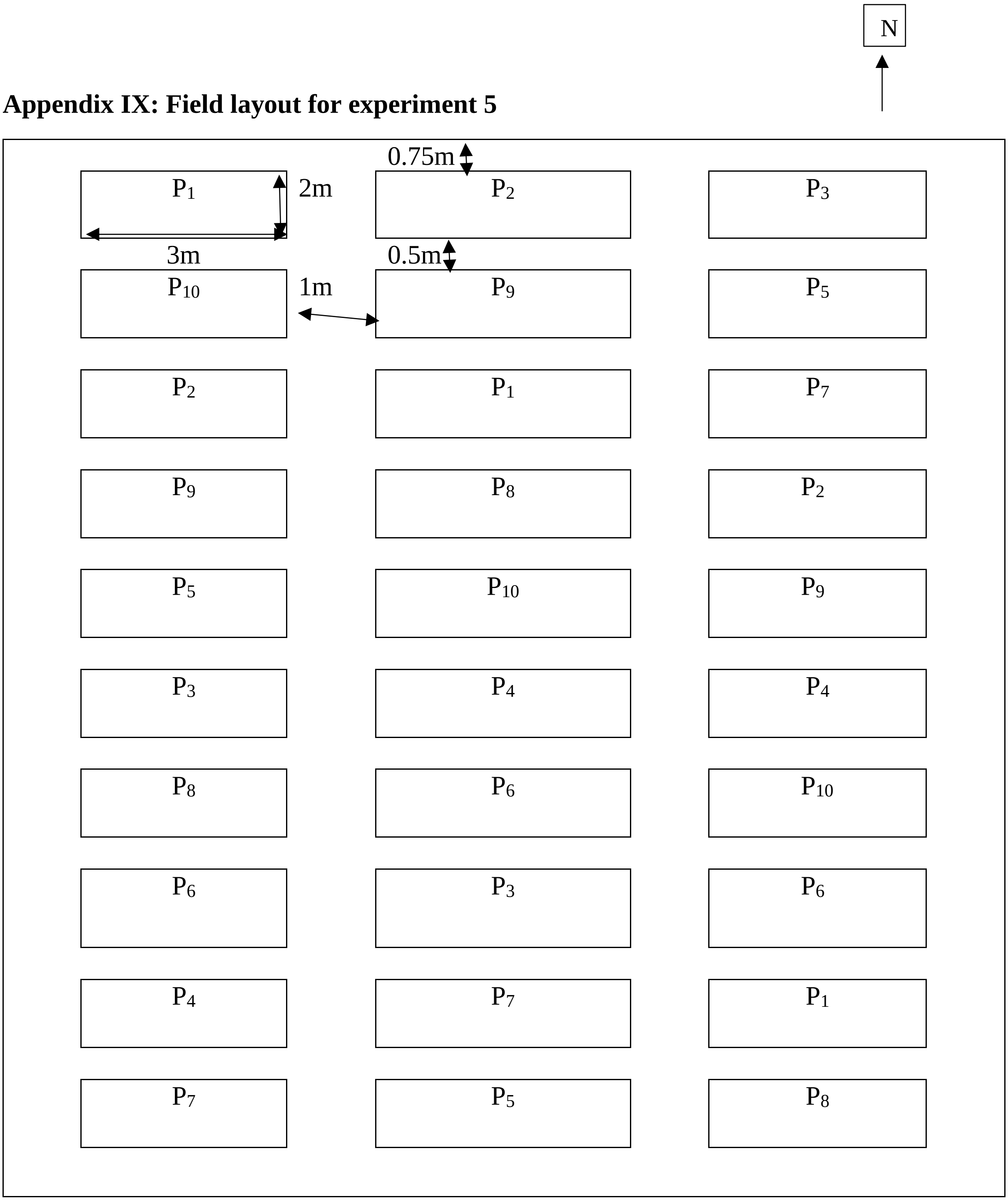
Appendix VII: Field layout for experiment 3



Appendix VIII: Field layout for experiment 4



Appendix IX: Field layout for experiment 5



Appendix X: Analysis of variance of the data for experiment 2

1. Shoot infestation

Source of variance	Degrees of freedom	Mean square				
		Vegetative stage	Early fruiting stage	Mid fruiting stage	Late fruiting stage	Average
Replication	2	11.828	6.903	15.625	0.493	4.422
Factor A	12	21.075	28.33	81.512	9.102	8.168
Error	24	4.685	7.214	15.438	1.628	2.296

2. Fruit infestation by number

Source of variance	Degrees of freedom	Mean square			
		Early fruiting stage	Mid fruiting stage	Late fruiting stage	Average
Replication	2	0.493	8.845	1.256	0.00
Factor A	12	9.102	98.012	235.991	58.743
Error	24	1.628	55.095	2.645	0.017

3. Fruit infestation by weight

Source of variance	Degrees of freedom	Mean square			
		Early fruiting stage	Mid fruiting stage	Late fruiting stage	Average
Replication	2	0.002	0.124	0.014	1.926
Factor A	12	16.071	385.633	1.469	123.315
Error	24	0.019	0.089	0.00	2.073

4. Number of branches and number of leaves

Source of variance	Degrees of freedom	Mean square		
		Scale 1 (1-2 bores/fruit)	Scale 2 (3-4 bores/fruit)	Scale 3 (>5 bores/fruit)
Replication	2	0.00	18.291	0.00
Factor A	12	1.688	340.573	0.984
Error	24	0.001	18.916	0.00

5. Number of branches and number of leaves

Source of variance	Degrees of freedom	Mean square	
		Branch (No./plant)	Leaf (No./plant)
Replication	2	0.016	0.015
Factor A	1	82.14	163.737
Error	18	0.00	0.006

6. Number of fruits/plant, single fruit length (cm), fruit girth (cm) and single fruit weight (g)

Source of variance	Degrees of freedom	Mean square			
		No. of fruits/plant	Single fruit length (cm)	Fruit girth (cm)	Single fruit weight (g)
Replication	2	1.564	3.179	331.485	0.001
Factor A	12	960.141	220.222	332.04	9.734
Error	24	0.814	5.641	37.485	0.001

7. Yield (kg/plot)

Source of variance	Degrees of freedom	Mean square
Replication	2	0.00
Factor A	1	15.483
Error	18	0.001

8. Moisture percent in leaves

Source of variance	Degrees of freedom	Mean square			
		Vegetative stage	Early fruiting stage	Late fruiting stage	Mean
Replication	2	1.462	0.231	0.346	0.063
Factor A	12	6.299	0.145	6.092	1.042
Error	24	0.85	0.12	0.67	0.23

9. Trichome hair density (no./cm^2)

Source of variance	Degrees of freedom	Mean square				
		Top first leaf	Top third leaf	Top fifth leaf	Top seventh leaf	Mean
Replication	2	0.006	0.016	0.009	0.012	0.00
Factor A	12	21.713	2.097	12.765	1.87	15.998
Error	24	2.071	0.178	1.332	0.003	0.264

10. Thorn density (No./leaf or stem)

Source of variance	Degrees of freedom	Mean square	
		Top first leaf	Stem (10 cm apical part)
Replication	2	0.009	0.014
Factor A	1	5.484	1.846
Error	18	0.00	0.00

Appendix XI: Analysis of variance of the data of experiment 3

1. Capturing capacity of pheromone traps

Source of variance	Degrees of freedom	Mean square
Replication	2	0.926
Factor A	2	9.593
Factor B	2	5.481
A×B	4	0.759
Error	16	0.551

2. Shoot infestation

Source of variance	Degrees of freedom	Mean square		
		No. of total shoot per plant	No. of infested shoot per plant	% shoot infestation
Replication	2	0.401	0.001	5.819
Factor A	2	0.28	0.381	103.66
Factor B	2	0.419	0.163	34.856
A×B	4	10.172	3.628	1105.949
Error	16	0.087	0.013	2.664

3. Fruit infestation

Source of variance	Degrees of freedom	Mean square	
		% Fruit infestation by number	% Fruit infestation by weight
Replication	2	17.417	9.74
Factor A	2	1176.387	7417.475
Factor B	2	2611.587	874.564
A×B	4	383.399	125.497
Error	16	3.145	11.758

4. Fruit yield

Source of variance	Degrees of freedom	Mean square	
		Fruit yield (kg/plot)	Fruit yield (ton/ha)
Replication	2	0.004	0.00
Factor A	2	20.523	0.132
Factor B	2	4.189	0.022
A×B	4	0.377	0.002
Error	16	0.001	0.00

Appendix XII: Analysis of variance of the data of experiment 4

1. Shoot infestation

Source of variance	Degrees of freedom	Mean square		
		No. of shoot per plant	No. of infested shoot per plant	% Shoot infestation
Replication	2	0.08	0.031	2.237
Factor A	9	21.308	2.167	821.896
Error	15	0.285	0.009	2.168

2. Fruit infestation by number

Source of variance	Degrees of freedom	Mean square		
		Number of fruit	Number of infested fruit	% Fruit infestation
Replication	2	4.633	0.433	1.912
Factor A	9	778.033	132.207	1432.361
Error	15	1.693	0.476	5.742

3. Fruit infestation by weight

Source of variance	Degrees of freedom	Mean square			
		Weight of fruit	Weight of infested fruit	Weight of healthy fruit	% Fruit infestation
Replication	2	0.00	0.00	0.00	0.345
Factor A	9	0.696	1.392	2.556	1732.438
Error	15	0.001	0.001	0.002	1.055

4. Length of healthy fruit, girth of healthy fruit, length of infested fruit and girth of infested fruit

Source of variance	Degrees of freedom	Mean square			
		Length of healthy fruit (cm)	Girth of healthy fruit (cm)	Length of infested fruit (cm)	Girth of infested fruit (cm)
Replication	2	0.002	0.001	0.011	0.00
Factor A	9	7.819	82.685	2.728	32.331
Error	15	0.001	0.001	0.001	0.001

5. Number of bore, edible fruit weight and non-edible fruit weight

Source of variance	Degrees of freedom	Mean square		
		Bore	Edible fruit weight (g)	Non-edible fruit weight (g)
Replication	2	4.433	0.00	0.001
Factor A	9	5.633	2.085	17.584
Error	15	0.253	0.00	0.016

6. Yield

Source of variance	Degrees of freedom	Mean square	
		Yield/plant	Yield/plot
Replication	2	0.00	0.001
Factor A	9	13.077	1.404
Error	15	0.001	0.00

Appendix XIII: Analysis of variance of the data of experiment 5

1. Shoot infestation

Source of variance	Degrees of freedom	Mean square		
		No. of shoot per plant	No. of infested shoot per plant	% Shoot infestation
Replication	2	0.001	0.022	2.448
Factor A	9	8.891	2.369	662.648
Error	18	0.039	0.01	1.321

2. Fruit infestation by number

Source of variance	Degrees of freedom	Mean square		
		Number of fruit	Number of infested fruit	% Fruit infestation
Replication	2	2.10	0.40	1.314
Factor A	9	300.389	96.181	1603.511
Error	18	3.10	0.437	7.552

3. Fruit infestation by weight

Source of variance	Degrees of freedom	Mean square			
		Weight of fruit	Weight of infested fruit	Weight of healthy fruit	% Fruit infestation
Replication	2	0.003	0.00	0.002	0.466
Factor A	9	0.785	0.472	2.448	1688.064
Error	18	0.002	0.001	0.002	1.701

4. Length of healthy fruit, girth of healthy fruit, length of infested fruit and girth of infested fruit

Source of variance	Degrees of freedom	Mean square			
		Length of healthy fruit (cm)	Girth of healthy fruit (cm)	Length of infested fruit (cm)	Girth of infested fruit (cm)
Replication	2	0.002	0.001	0.00	0.001
Factor A	9	1.928	6.166	2.583	2.30
Error	18	0.002	0.001	0.001	0.001

5. Number of bore, edible fruit weight and non-edible fruit weight

Source of variance	Degrees of freedom	Mean square		
		Bore	Edible fruit weight (g)	Non-edible fruit weight (g)
Replication	2	10.033	0.00	0.00
Factor A	9	8.089	0.017	0.663
Error	18	0.256	0.00	0.001

6. Yield

Source of variance	Degrees of freedom	Mean square	
		Yield/plant	Yield/plot
Replication	2	0.00	0.00
Factor A	9	12.179	0.09
Error	18	0.001	0.00