COMPARING INCIDENCE AND INFESTATION OF INSECT PESTS IN BT AND NON-BT BRINJAL AND THEIR CHEMICAL MANAGEMENT

SAIFULLAH OMAR NASIF

DEPARTMENT OF ENTOMOLOGY
SHER-E-BANGLA AGRICULTURAL UNIVERSITY
DHAKA-1207

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SAIFULLAH OMAR NASIF
REGISTRATION NO.: 12-04861

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APPROVED BY:

Prof. Dr. Mohammed Sakhawat Hossain
Supervisor
Department of Entomology
SAU, Dhaka

Prof. Dr. Md. Abdul Latif
Co-Supervisor
Department of Entomology
SAU, Dhaka

Dr. Mst. Nur Mohal Akhter Banu
Chairman
Department of Entomology
and
Examination Committee

DEPARTMENT OF ENTOMOLOGY

Sher-e-Bangla Agricultural University

Sher-e-Bangla Nagar, Dhaka-1207

CERTIFICATE

This is to certify that the thesis entitled '**Comparing Incidence and Infestation of Insect Pests in Bt and non-Bt brinjal and Their Chemical Management'** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **Master of Science in Entomology,** embodies the result of a piece of *bonafido* research work carried out by **Saifullah Omar Nasif, Registration number: 12-04861** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: December, 2017
Dhaka, Bangladesh

Dr. Mohammed Sakhawat Hossain
Supervisor
&
Professor
Department of Entomology
Sher-e-Bangla Agricultural
University
Dhaka-1207

Dedicated

To

The People Beseeching

Justice

ABBREVIATIONS

Agro Ecological Zone	=	AEZ
And others (Co-workers)	=	*et al.*
Brinjal Shoot and Fruit Borer	=	BSFB
Bacillus thuringiensis	=	Bt
Centimeter	=	cm
Coefficient of Variation	=	CV
Degree centigrade	=	^{o}C
Degree of freedom	=	df
Example	=	viz.
Fiscal Year	=	FY
Genetically Modified	=	GM
Least significant difference	=	LSD
Million tons	=	mt
Nitrogen	=	N
Non-significant	=	NS
Per Hectare	=	ha^{-1}
Percentage	=	%
Phosphorus	=	P
Potassium	=	K
Randomized Complete Block Design	=	RCBD
Relative humidity	=	% RH
Standard Week	=	SW

Sher-e-Bangla Agricultural University	=	SAU
Standard Error	=	SE
that is	=	i.e.
tons	=	t

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ABSTRACT

This study compared the incidence and infestation of the major insect pests and their susceptibility to insecticides in two different genotypes of brinjal; BARI Bt brinjal 2 and BARI brinjal 4. The experiment was conducted on central farm of Sher-e-Bangla Agricultural University, Dhaka in rabi season 2017-18. The experiment used a completely randomized 2 x 4 factorial design, with four replications. The first factor refers to the corresponding Bt and non-Bt brinjals, and the second factor refers to the different chemical treatments (imidacloprid 0.5 mlL^{-1} water, Spinosad 0.4 mlL^{-1} water, malathion 2 mlL^{-1} water and control). Both the varieties showed lower infestation in vegetative stage and peak infestation in reproductive stage. Results revealed that the lowest population of sucking pests such as jassid, aphid and whitefly (6.41, 8.22, 6.52 and 10.8, 8.33, 8.45 per six leaves at vegetative and fruiting stage respectively) occurred in non-Bt brinjal and from imidacloprid. Spinosad and Bt brinjal showed higher efficiency in controlling epilachna beetle and brinjal shoot and fruit borer (1.25 $plants^{-1}$, 0.93% and 1.31 $plants^{-1}$, 2.71% in shooting and fruiting stage respectively). So, imidacloprid and spinosad can be used in controlling sucking pests and chewing pests of brinjal respectively.

CHAPTER I

INTRODUCTION

Brinjal (*Solanum melongena* L.) is a salient solanaceous, agronomically important and non-tuberous vegetable across the world and also popularly known as eggplant, aubergene, melongene, garden egg or guinea squash (Yiu 2016). The family solanaceae has 75 genera and more than 2000 species. It is a supreme vegetable in Bangladesh, easy to cultivate and ranked second after potato in context of production. It is grown on nearly 50,394 hectares (BBS 2017). Having almost 95 percent of water, brinjal possess very low caloric value (24 kcal/100 g) (Chadha and Kalloo 1993).

Being composed of multifarious nutritive compounds, brinjal is considered among the healthiest vegetables. It contains high content of vitamins, minerals and bioactive compounds those are remunerative to human health. In this respect, brinjal is ranked among the top 10 vegetables in terms of oxygen radical absorbance capacity (Cao *et al.* 1996).

Among the various causes of low productivity of the brinjal one of the most important factors acting against increasing the yield is the damage inflicted by the insect pests (Regupathy *et al.* 1997). Among the insect pests infesting brinjal, the major ones are brinjal shoot and fruit borer, *Leucinodes orbonalis* (Guen.); whitefly, *Bemicia tabaci* (Genn.); epilachna beetle, *Epilachna vigintioctopunctata*; leafhopper, *Amrasca biguttula biguttula* (Ishida); mealy bug, *Coccidohystrix insolita* (Green); thrips, *Thrips palmi*, red mite *(Tetranychus urticae) etc.* The losses caused by various pests were estimated to be ranging from 28-85% (Ahmad 1974). Brinjal shoot and fruit borer, *Leucinodes orbonalis* Guenee is the key pest of brinjal (Saimandir and Gopal 2012, Chakraborty and Sarkar 2011, Latif *et al.* 2010) incurring severe damage in nearly all the brinjal growing regions (Dutta *et al*. 2011) and particularly, is most devastating in south Asia (Thapa 2010). Sucking insect pests such as jassid, aphid, whitefly are also the serious pests of brinjal.

Only the caterpillars of BSFB cause 78.66% damage to top shoot in vegetative phase and then shifted to flowers and fruits with infestation reaching 67% in reproductive phase (Singh *et al.* 2000). Because of its devastating effect inside fruit, the fruits wind up noticeably unmarketable and yield reduction up to 90 percent (Baral *et al.* 2006). In order to control such notorious pests, farmers in Bangladesh apply insecticides unwisely. Even, to control BSFB infestation, famers apply insecticides 140- 180 times in a cropping season. Huge chemicals in environment leads to pollution that poses serious health risk among mankind. Host-plant resistance is one of the ways that can omit pesticide use; thus transgenic/genetically modified technology has emerged as an alternative to chemicals in controlling insect pests. Nevertheless, the first GM food crop viz. Bt brinjal, has been developed by India based Maharashtra Hybrid Seed Company (Mahyco) by using a *Bacillus thuringiensis* cry1Ac gene to transform brinjal to be resistant in BSFB (Shelton *et al.* 2017). Bangladesh approved four Bt brinjal varieties in 2013, and subsequently distributed to selected farmers in major brinjal growing regions across the country.

From the very beginning of Bt brinjal propaganda, controversy is also going with the flow. Many argued on the so-called sustained resistance of Bt gene upon BSFB. It needs to regular observation whether Bt gene is showing its performance as described or not. Moreover, Bt brinjal is not designed to control sucking pests. So, need arises to check the susceptibility of Bt brinjal against sap sucking insect pests of brinjal since very limited research have been done to answer the questions.

In order to evolve and design pest management practices based on sound ecological footing and economically feasible, information on the pest complex is a pre-requisite. Similarly, influence of weather factors on pest population differs in different region; hence sufficient knowledge about the seasonal activity of the pest is necessary for adopting suitable control measures in a particular region. It is notable that, no work has been done in Bangladesh which compared the seasonal abundance of insect pests in Bt brinjal with its corresponding non-Bt brinjal variety.

Management of insect pests of brinjal in Bangladesh is basically based on chemical insecticides. Among various insecticides available in the market, few are effective against BSFB as well as sucking pests of brinjal. As many insecticides are under investigation to check their efficacy against brinjal pests, many of them reported as resistant as well as relatively toxic to human (Teotia and Singh 1971). It is of urgent emergency to find out most effective in relation to conventional insecticides and which are less toxic to manage pest population.

Sequel to the above, present research has been undertaken:

1. To Study and compare the incidence and infestation of major insect pests in Bt and non-Bt brinjal
2. To study the susceptibility of Bt brinjal against sucking pests of brinjal
3. To assess the efficacy of promising insecticides in relation to conventional insecticides against pest complex of brinjal.

CHAPTER II

REVIEW OF LITERATURE

An attempt has been made to bring out review relating to the "Comparing incidence and infestation of insect pests in Bt and non-Bt brinjal and their chemical management." A brief resume of the work done in the past by various workers given in this chapter.

2.1. Brinjal: A multifarious vegetable

Brinjal or eggplant (*Solanum melongena* L.) is the admired, common and predominant non-tuberous vegetable in Bangladesh and other parts of the world. The genus *Solanum* under the family solanaceae is consists of diverse flowering plants among which few high-value economically important food crops exist (Annon. 2018). Brinjal is one of the prominent food crops among them. It is well known for its high-water content and low calorific value (Kandoliya *et al*. 2015). According to Wankhede (2009), brinjal fruit contains moisture 91.5 per cent, protein 1.3 per cent, minerals 6.5 per cent, carbohydrates 6.4 per cent, calcium 0.02 per cent, phosphorus 0.06 per cent and iron 1.3 per cent respectively. It also contains vitamin A 5 mg /100 g, vitamin B 45 mg / 100 g, nicotinic acid 0.08 mg / 100 g, riboflavin 90 mg / 100 g, vitamin C 23 mg / 100 g.

Apart from the essential minerals it also contains some exclusive antioxidants such as arginine, 5-HT, delphinidine-3 Bioside (nasunin), solasodine, tryptophan etc (Rai and Pandey 1997). These compounds made brinjal fruits to be ranked amongst the top ten vegetables in terms of antioxidant capacity (Cao *et al.* 1996).

Beside its food value, brinjal has immense importance in terms of medicinal value. Fruit phenols such as anthocyanins and strychnine from brinjal have potential to cure a variety of disease like cancer, hypertension, hepatosis (Magioli and Mansur

2005 and Silva *et al.* 1999). Mutalik *et al.* (2003) reported that brinjal has beneficial effects in the treatment of inflammatory stress, cardiac debility, neuralgias, bronchitis and asthma. A study by Igwe *et al.* (2003) suggested that brinjal can have positive consequences on visual function. A 1984 study by Vohora *et al.* revealed that brinjal contains fraction of crude alkaloid that has significant analgesic effect. Such nutritional and medicinal qualities of brinjal make it worth consuming.

2.2. Present scenario of brinjal cultivation in Bangladesh

Being a low-cost vegetable in Bangladesh, farmers used to cultivate brinjal in their cropland. Brinjal is cultivated in Bangladesh in all the year round. But due to the diverse climatic condition in Kharif season, the area under kharif cultivation is low in comparison to rabi cultivation. The area and production are diminishing compared the previous year.

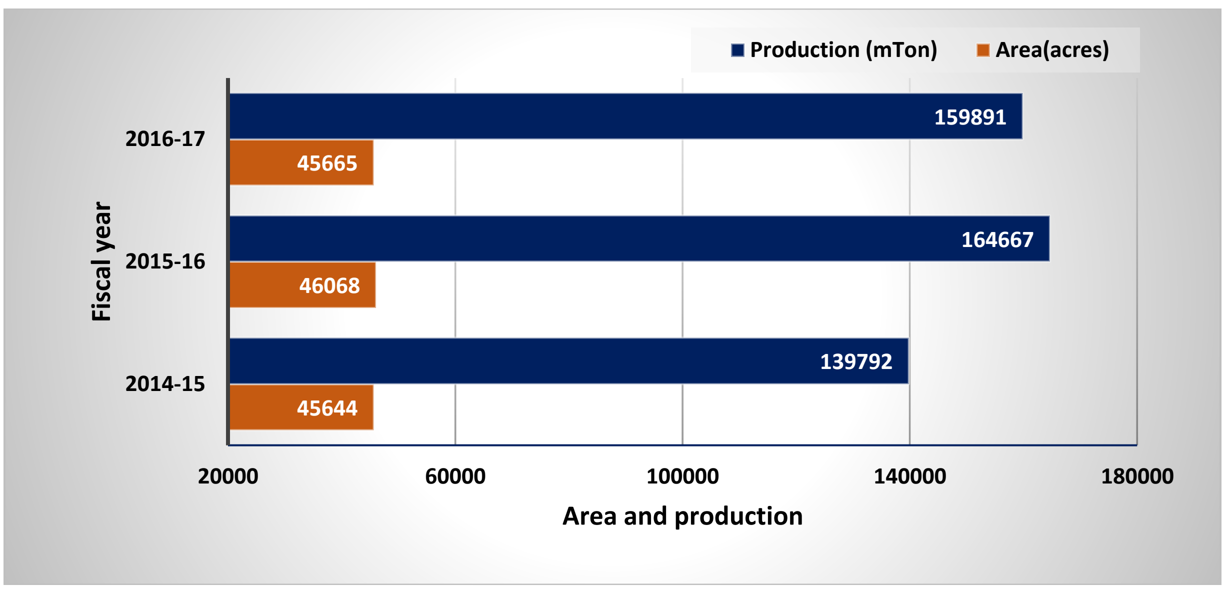

Figure 1: Area and production of brinjal during kharif season in Bangladesh
Source: BBS 2018

In 2015-16, the total production (Figure 1) of brinjal in kharif season was 164667 mt in 46068 acres of land where, in 2016-17 the production declined to 159891 mt and the land reduced to 45665 acres. However, the production and area coverage are somewhat more than that of 2014-15 FY. In 2014-15, total brinjal production was 139792 mt and the area under cultivation was 45644 acres. The favourable temperature and relative humidity in the winter season facilitates higher production in rabi season. It is evident from that figure 2 that both the area coverage and in terms of production rabi season have higher position.

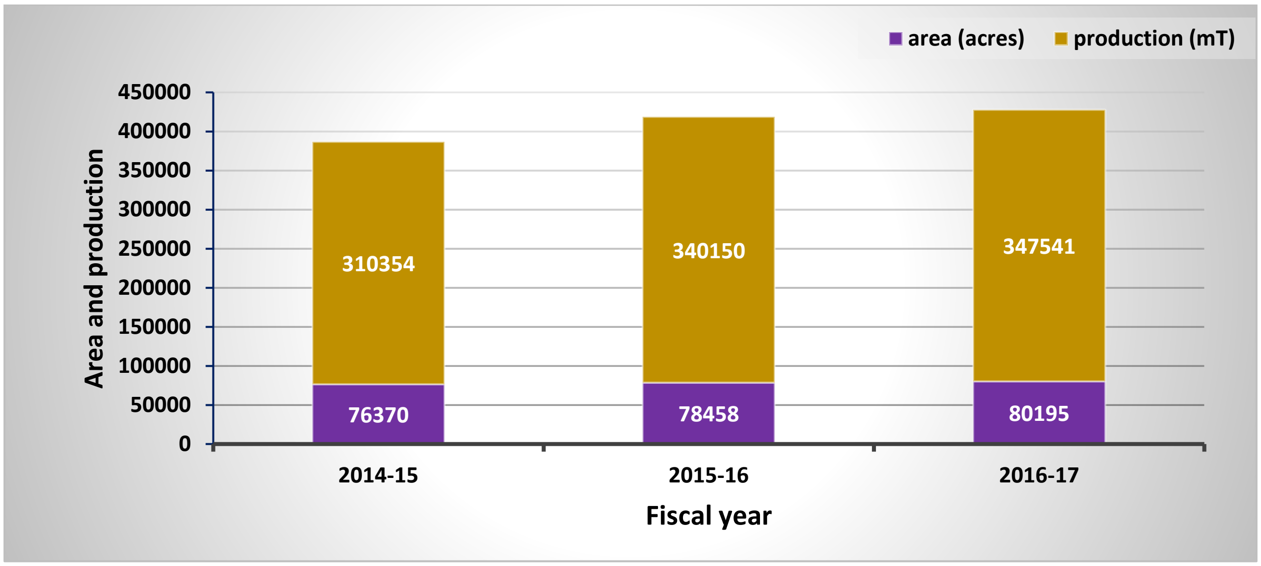

Figure 2: Area and production of brinjal during rabi season in Bangladesh
Source: BBS 2018

The rabi cultivation is increasing gradually unlike of kharif season. In 2014-15, where the brinjal cultivation was done in 76370 acres, acreage area increased to 78458 acres in the next year with an increased production of 340150 mT from 310354 Mt. In 2016-17, the total production increased to 347541 mT with an area coverage of 80195 acres. According to BBS data, among the vegetables grown in Bangladesh, brinjal constitutes 12.56 percent area and ranked the apex position among other vegetables.

2.3. Bt brinjal adoption in Bangladesh

Upon the application of BARI (Shelton *et al.* 2018) to the National Technical Committee on Crop Biotechnology (NTCCB), NTCCB core committee; with the follow-up of National Committee on Bio-safety released four varieties (BARI Bt brinjal varieties 1, 2, 3 and 4). However, government during the period granted approval for 'limited' cultivation. During 2014, seedlings of these varieties were distributed among some selected farmers across the country. Bt Brinjal-1 variety, popularly referred as Uttara, was distributed in Rajshahi region; Bt Brinjal-2 (former Kajla) in Barisal region; Bt Brinjal-3 (Nayantara) in Rangpur and Dhaka regions; and Bt Brinjal-4 variety, Iswardi/ISD006, was planted in Pabna and Chittagong regions of the country. However, according to Choudhury *et al*. (2014), Bt gene would be incorporated in more five promising brinjal varieties in Bangladesh namely Dohazari, Shingnath, Chaga, Islampuri and Khatkatia. Bangladesh Agricultural Development Corporation (BADC) in collaboration with Bangladesh Agricultural Research Institute (BARI) is currently responsible for multiplication and distribution of Bt brinjal varieties in Bangladesh.

2.4. Insect pests of brinjal, their host preference, nature of damage and succession

Nayer *et al.* (1995) reported that brinjal is attacked by 53 species of insect pests. A pest risk analysis study was undertaken in Bangladesh in 2016 by Hossain *et al.* They reported 20 insect pests in brinjal among which 19 insects and 1 mite pest found. Among them brinjal shoot and fruit borer, epilachna beetle, jassid, aphid and whitefly were described as major insect pests of brinjal.

2.4.1. Brinjal shoot and fruit borer (BSFB), *Leucinodes orbonalis* Guen.

BSFB is the most notorious pest of brinjal in Bangladesh. Being phytophagous, BSFB is under the order lepidoptera and Alam and Sana (1962) reported that the genus *Leucinodes* has three main species namely *L. orbonalis* Guen., *L. diaphana* Hamps and *L. apicalis* Hamps.

2.4.1.1. Host preference

BSFB attacks not only brinjal but other solanaceous crops. Study revealed (Karim 1994) that wild relatives of genus *Solanum* can be attacked by this notorious pest. Caterpillar of this moth feed on pea pods (Alam and Sana 1962). *Solanum nigrum*, *Solanum myriacanthum* can potentially play significant role as alternative host of brinjal shoot and fruit borer. (CABI 2007; Ishaque and Chaudhuri 1984).

2.4.1.2. Nature of damage

L. orbonalis attacks for the most part on blossoming, fruiting and vegetative developing stage on fruits/units, developing parts and inflorescence (CABI 2007). Like other members of the order lepidoptera, *L. orbonalis* goes through four growth stages: egg, larva, pupa and adult. The larval period is the longest, followed by pupal and incubation period. Oviposition takes place during the night and eggs are laid singly on the lower surface of the young leaves, green stems, flower buds, or calyces of the fruits and number of eggs laid by a female varies from 80 to 253 (Taley *et al.*1984; Alpuerto 1994). The eggs are laid in the early hours of the morning singly or in the batches on the ventral surface of the leaves (CABI 2007). Eggs are flattened, elliptical with 0.5 mm in diameter and colour is creamy-white but change to red before hatching (Alam *et al*. 2006). The egg takes incubation period of 3-5 days in summer and 7-8 days in winter and hatch into dark white larvae. The larval period lasts 12 - 15 days during summer and 14 - 22 days during winter season (Rahman 2006). Larvae pass through at least five instars (Shaukat *et al*. 2018; Atwal 1976) and there are reports of the existence of six larval instars (FAO 2003; Baang and Corey 1991).

The higher percent of the larvae was in fruits taken after by shoots, blossoms, bloom buds and midrib of leaves (Alpuerto 1994). Inside one hour in the wake of bring forth, *L. orbonalis* caterpillar drills into the closest delicate shoot, bloom, or fruit. Not long after in the wake of drilling into shoots or fruits, they attachment or stop up the passageway opening (nourishing passage) with excreta (Alam *et al*. 2006).

Watching the drilling openings, the pervaded fruits can be distinguished without much of a stretch. Furthermore, the dull shaded excreta can be seen without much effort to the opening of pervaded fruits. Optional pervasions by specific microorganisms may create additional decay of the fruits (Islam and Karim 1991) and make them at last unfit for human consumption.

In young plants, caterpillars are accounted for exhausting inside petioles and midribs of extensive leaves (AVRDC 1998; Alpuerto 1994; Butani and Jotwani 1984) along these lines shrivelling, drop off and shrink of the young shoots prompting delay on shoot development, decrease on yield and yield parameter. Larval bolstering inside the fruit brings about pulverization of fruit tissue. In serious cases, spoiling of fruit was normal (Neupane 2001). Larval nourishing in bloom was uncommon, if happen, inability to shape fruit from harmed blossoms (Alam *et al.* 2006). The caterpillars of *L. orbonalis* bore into the developing points of young tender shoots and a wilted drooping shoots a run of the mall manifestation, which at last shrivels away. The fruiting beads droop down while the fruits indicate round about openings, which are the leave gaps.

2.4.1.3. Incidence of brinjal shoot and fruit borer

L. orbonalis is dynamic during the time at places having moderate atmosphere yet its movement is antagonistically influenced by serious chilling reported by Naqvi *et al.* (2009). They found that BSFB pervasion on brinjal started in August and achieved its crest in October and afterward began declining. According to Farman *et al*. (2016), a low infestation (18.66%) of borer was noted in the third week of May, severe infestation (75.50%) in the first week of August, and a high infestation (42.64%) in the last week of September at the end of the crop growing season. Ghosh and Senapati (2009) found that this pest causes the most destruction and is most dynamic amid the late spring months, i.e., from May to August. It turns out to be less dynamic amid the winter months, especially in December and January. Varma *et al.* (2009) considered the occurrence and plenitude of BSFB in Allahabad, India and watched the most elevated rate on brinjal in December. Patel *et al.* (1988) discovered shoot and fruit damage in brinjal by BSFB was higher in May transplanted (spring) crops than that in July and September transplanted (fall) crops. The damage caused by insect change from season to season since direct temperature and high moistness support the populace develop of brinjal shoot and fruit borer (Bhushan *et al.* 2011; Shukla and Khatri 2010). Areas having a hot and humid climate are conducive for its distribution and incidence. Patel *et al.* (1988) reported that summer season brinjal has more susceptibility than winter season brinjal. Pawar *et al.* (1986) found highest shoot infestation during mid-September while peak fruit infestation was reported during mid-November.

2.4.2. Epilachna beetle, *Epilachna dodecastigma*

Among the coccinellids, the beetles belonging to the subfamily Epilachninae constitute one-sixth species. Around 500 species have been found under the genus *Epilachna* (Jamwal *et al.* 2013). This pest is widely distributed in South East Asia, Australia, China, India and many other countries.

2.4.2.1. Host preference

Epilachna beetles are phytophagous in nature and attack a wide range of plants belonging to solanaceae, cucurbitaceae, fabaceae, convolvulaceae as well as malvaceae family. Brinjal, tomato, potato, tobacco, melon, cucumber, gourds, pumpkin and many other important food crops are frequently being under attack of epilachna beetle (Rath 2005; Ahmad *et al*. 2001). Its presence has also been recorded on some medicinal plants and other naturally occurring solanaceous plant like *Solanum nigrum* and *Solanum torvum* (Wilson 1989; Ganga and Chetty 1982).

2.4.2.2. Nature of damage

Infestation of epilachna beetle can significantly reduce yield by hampering crop growth and yield. (Maurice *et al*. 2013). Both adult and grub feed on brinjal leaves;

especially epidermal tissue of leaves, flowers and fruits, scrap the tissue and thus inflict serious damage of brinjal plant during the whole season i.e. seedling stage to maturity (Varma and Anandhi 2008; Ghosh and Senapati 2001; Reddy 1997; Imura and Ninomiya 1978). Srivastava and Katiyar (1972) stated 35-75 percent leaf injury caused by epilachna population. On the other hand, Rajagopal and Trivedi (1989) reported 80 percent damage by feeding of eilachna beetle. Mall *et al.* (1992) reported 60 percent fruit damage caused by this notorious pest. Jeyasankar *et al.* (2014) reported that epilachna beetle has developed resistance against many commercial insecticides.

2.4.2.3. Incidence of epilachna beetle

According to Omprakash and Raju (2014b), maximum temperature and minimum temperature has positive significant correlation with population dynamics which is negatively correlated with rainfall and humidity. But their results didn’t show conformity with the study of Haseeb *et al.* (2009). He reported that highest number of epilachna found during third week of February and reaching to the least during April. However, it started infestation from the initial crop growth period. And he found positive correlation of relative humidity and rainfall with the succession and population dynamics of epilachna beetle. Varma and Anandhi (2008) reported that epilachna started infestation by the first week of November with an average population of 2.85 beetles per plant and maximum infestation occurred in the third week of February with the first peak at third week of November. They also stated negative correlation between temperature and populace development however positive correlation among all other weather parameters. Research carried out by Venkatesha (2006) revealed that highest population of epilachna beetle found on mid-August then declined by the late August and became zero on October. They also showed that during peak period of infestation maximum temperature, minimum temperature and relative humidity were 27.5 ± 0.88^0C, 19.58 ± 0.49^0C and 75.55 ± 13.37 % respectively. Raghuraman and Veravel (1999) reported that epilachna infestation started from December and peak infestation was in February and March. However, Ghosh and Senapati (2001) stated Mid-September as the highly infested month. Ramzan *et al.* (1990) found 24-31^{0}C and 58-75% relative humidity conducive for epilachna population development.

2.4.3. Jassid, *Amrasca biguttula biguttula* Ishida

Jassid is a common sucking pest of brinjal and can be found throughout the world. This versatile pest is a cause of farmers tension due to its wide range of host preference and capability to cause huge damage. (Ghauri 1963).

2.4.3.1. Host preference

Besides living on brinjal and cotton mainly, jassids also harbour on various herb like plants and crop as well as on many weeds of solanaceae, malvaceae and Cruciferae family (Prasad and Logiswaran 1997b).

2.4.3.2. Nature of damage

Das and Islam (2014) claimed jassid as the second major pest of brinjal due to its high population intensity and damage severity. Ali *et al*. (2012) reported that brinjal is one of the most favourite host plants of *A. biguttula biguttula.* Many scholars identified jassid as major key pest of Brinjal (Latif *et al.* 2009; Iqbal *et al.* 2008). Iqbal *et al.* (2008) stated that oriental regions i.e. tropical and subtropical are suitable for jassid population due to the fact that the weather conditions prevailing in these regions are conducive for host-plant interaction. Jassid is phytophagous in nature and the extent of jassid damage to number and weight of brinjal could be as much as 54 percent (Mahmood *et al*. 2002). Jassid caused devastating effect in solanaceous crops and hampered the transportation process through the phloem tissues of plant and possibly introduced a toxin that is inhibitory to photosynthesis activity (Sharma and Chandar 1998). These authors also reported early damage in brinjal by jassid. Most importantly, they don't reduce the plant vigor by sucking cell sap only, also they spread mosaic virus disease as a vector and thus affect the fruit yield rigorously (Samal and Patnaik 2008). According to Deole (2008), jassids preferred brinjal cultivars those have smooth textured leaves than having leaves having leathery texture or leathery texture with spines. Ali *et al.* (2012) reported that the hair density and length of hair on lamina, midrib, and veins of brinjal had highly significant and negative correlation with the jassid population. The degree of trichomes on the leaves play important role in the plant defense particularly among phytophagous insects.

2.4.3.3. Incidence of jassid on brinjal

A population dynamics study by Saroj *et al.* (2017) brinjal jassid first reported during 32nd SW and were found up to 41st SW. Highest number of jassids (12.70 jassids/ leaf) was reported during 37th SW Gangwar and Singh (2014) carried out an experiment on succession of brinjal pest complex. They found jassid population from August to December i.e. the population appeared in the first week after transplanting and its population development continued up to the maturity stage of brinjal. Dabhi and Koshiya (2014) reported peak population of jassid during 16th, 18th, 24th, 33rd SW. Kadam (2003) development of jassid population was associated with Dhamdhere *et al*. (1995) observed peak population of jassid in the third week of September however, they found activity of jassid during both rabi and kharif season. Ali and Karim (1991) carried out an experiment on cotton jassid. They reported that highest number of jassids were found during 35 to 75 days after transplanting in kharif season and 65 to 135 days in rabi season. According to Prakash (1978) peak population of jassid observed during late September to mid-November.

2.4.4. Aphid, *Aphis gossypii*

Aphid belongs to the Aphididae family and hemiptera order. It's a major sucking pest of some commercially important food crop and phytophagous in nature. Different species of aphid such as *Aphis craccivora, Aphis gossypii, Myzus persicae* feed on brinjal, tomato and many other vegetables as well as cereal crops (Alam 1969).

2.4.4.1. Host preference

Aphid is a versatile crop pest and can be found all over the world. Singh *et al.* (2014) carried out an experiment for host plants of *A. gossypii* in India and recognized 29 plant species of the family Solanaceae to be host for the *A. gossypii* and recognized *C. annuum* as the most important host. Shakeel *et al.* (2014) reported aphid as a serious threat to agricultural crops. Evans and Halbert (2007) prepared a checklist of aphids of Honduras on different host plants and reported *A. gossypii* and *M. persicae* on *Solanum melongena*. Nayer *et al.* (1976) said that *Aphis craccivora* is the most common aphid species and found to infest a wide range of vegetables and pulse crops.

2.4.4.2. Nature of damage

Miller *et al.* (2009) stated that the direct consequences of aphid infestation causes yield losses, decline in quality and increased agricultural potential risks. Aphids can accumulate in high densities on young tender parts of the plants because they have high colonising capacity; eventually they suck the sap especially from the lower side of the young leaves. Infested plants turn pale, leaves become distorted, curled and crinkled leading to stunted growth of the plants. Aphids secrete honey dew, which attracts ants and which can further deter natural enemies of aphids and may turn out to be pests on brinjal plants, especially damaging the flowers. Excessive honey dew secretion can lead to the development of sooty mould which affects the photosynthesis and if present on the fruits reduce the size as well as the market value of the brinjal (Ghosh *et al.* 2004).

2.4.4.3. Incidence of aphid in brinjal

Shakeel *et al*. (2014) reported that the aphid population development in brinjal had a significant negative correlation with the maximum temperature, minimum temperature and rainfall, whereas relative humidity was positively correlated with the population size. They found peak aphid population in February which decreased with increasing temperature. Rajabpour and Yarahamadi (2012) studied succession of *A. gossypii* on *Hibiscus rosa-chinensis*, and found that the aphids started infesting the crop in November and attained a peak density during January-February with aggregated population in the field. Shah *et al*. (2009) reported *A. gossypii* populations on okra crop to be prevalent from first week of May to first week of September with highest infestation during last week of July. A research by Touhidur *et al*. (2006) revealed that population abundance and spatial distribution of *A. gossypii* varied with weather parameters. And peak aphid population were found on 56 DAT. According to Rondon *et al.* (2005) peak aphid nymphal density was in March whereas peak adult aphid population abundance recorded in February and March. Musa *et al.* (2004) did a monitoring work in potato fields for *M. persicae* in Kosovo and compared three locations and two varieties. Results revealed that aphids occurred in May-June and then were present throughout the season with peak activity during July-August. Aphid population decreases to negligible from last week of November to first week of December. Karim *et al.* (2001) in their experiment stated that *A. gossypii* population started in August and attained a peak period in January and almost negligible population in April on *Solanum melangena* L. in Bangladesh. Second peak infestation was observed during May-June; a study by Tancik (2001) said.

2.4.5. Whitefly, *Bemisia tabaci*

Whitefly is phytophagous in nature and a serious pest of crops. It belongs to Aleyrodidae family and Homoptera order. There are 12,000 different species found worldwide (Bartlett and Gawel 1993). Importantly, whitefly includes 41 distinctly isolated species population with 24 populations of a specific biotypes. (Perring 2001). Whitefly can cause considerable yield loss and damage to brinjal plants (Mandal *et al.* 2010).

2.4.5.1. Host preference

Whitefly is the most abundant and versatile crop pests which infest around 600 different crop plants and wild plants (Cueller and Morales 2006). Arnal *et al*. (1993) in his research, reported that whitefly can attack 500 species of plants belong to 74 taxonomic families. Among the plants squash, tomato, brinjal, potato, pumpkin, cucurbits, okra, beans are noteworthy. Parthenium is one of the most favourite host of whitefly. It also feeds on some weed like *Itsit*, datura, milkweed, *Chenopodium* sp.

2.4.5.2. Nature of damage

Whitefly causes crop damage by causing chlorosis, leaf withering, premature leaf drops and wilting. As a sap sucking insect, it feed the phloem sap of plant tissue (Brown *et al.* 1995). Followed by feeding, plant physiological disorder happens, because of contamination of the crops with excreted honeydew by whitefly which leads to development of sooty mould thus reducing the effective leaf area for photosynthesis (Henneberry *et al*. 2001). This also results in irregular ripening of fruit (McKenzie & Albano 2009). A most important fact is whitefly plays as a vector of virus disease and surprisingly, it transmits nearly 114 virus species and some can bring havoc to crops (Jones 2003; Byrne & Bellows 1991). Due to the fact that whitefly lives on the lower side of the leaves, it becomes trouble worthy to control whitefly with contact insecticides (Zhang *et al.* 2004). Whitefly is also reported to be possessed resistance to a wide range of insecticides (Dennehy *et al.* 2006).

2.4.5.3. Incidence of Whitefly, *Bamisia tabaci* Genn.

Sharma (2012) reported that the activity of white fly was started from second week of August (33^{th} SW) and continued up to the crop period i.e. first week of February. The maximum white fly population (19/ plant) was recorded in last week of September (39^{th} SW), when maximum and minimum temperature and humidity were 34.3˚C, 26.2˚C and 71.7 per cent respectively. According to the experiment of Ramrao (2012), whitefly was first recorded in the third week of December (50^{th} SW) and the activity of the pest continued from second week of December to first week of May. Though, he stated that weather factors have no significant effect on population dynamics, on the contrary Prasad and Logiswaran (1997b) reported that relative humidity showed positive impact on pest population. Fauziah *et al.* (2009) carried out an experiment on population ecology of whitefly on brinjal and observed peak larval population at 4 to 7 weeks after transplanting and maximum numbers were observed on the middle canopy of the plants. In case of *B. tabaci* on cucumber, higher number of adults and nymphs were recorded on older plants. Khalid *et al.* (2009) studied population abundance of whitefly on chilli crop by using yellow sticky trap and reported maximum population at 77 DAT and minimum population at 7 DAT. Rainfall, sunshine hours and RH had no significant correlation with the populations whereas wind speed had a positive correlation. Naik *et al.* (2009) reported that the peak activity of the pest was recorded during third week of February.

2.5. Management of insect pest complex of brinjal

Due to the huge production loss and crop damage inflicted by insect pest complex of brinjal, it is important to summarize the management practices and technology suggested by other scholars. Therefore, pertinent literatures were gleaned and overviews prepared for the management of the major insect pests of brinjal with consideration of supporting literature helpful for management.

2.5.1. Cultural control

The cultural practice can help in controlling pest population. Pruning is one of the best ways to control pest abundance especially BSFB. According to Paul *et al.* (2015), intercropping of brinjal with coriander helped in reducing BSFB infestation. Salunke and Shyam (2015) reported that color of brinjal especially blue or pink attracts BSFB moth to lay eggs. All crop stubbles should be removed soon after harvesting. There should be some distinct isolation distance to grow seedling from the stubble heaps (Rahman *et al.* 2009; Satpathy 2005; Arida *et al.* 2003; Talekar 2002). Neupane (2000) reported that pruning of infested twigs and branches prevents the further spreading of *L. orbonalis* in the field. As a part of crop sanitation procedure, the intermittent pinching/pruning of damaged shoot, their collection and further burrying or burning helps to decline pest infestation (Ghimire *et al.* 2007; Som and Maity 1986; Rao and Rao 1955). Among other pest management measures, the removal of the alternate hosts of the pest and mechanical barriers are noteworthy. *Solanum nigrum* Linnaeus, *Solanum indicum* Linnaeus, *Solanum torvum* Swartz, *Solanum myriacanthum* Dunal, *Lycopersicon esculentum* Mill and *Solanum tuberosum* Linnaeus were recorded as alternative food source of the *L. orbonalis* (Reddy and Kumar 2004; Murthy and Nandihalli, 2003). Refuges crop can help in managing sucking pests of brinjal. Landis *et al.* (2000) reported that a pest-suppressive agroecosystem which will be designed to facilitate a suitable intercrop as refuge crop will help in controlling sucking pests of brinjal. *B. thuringiensis*-transgenic brinjal plants are highly resistant to damage by lepidopteran pests, and consequently, the application of chemical insecticides can be greatly reduced. This makes Bt brinal a valuable component of integrated pest management programs, with many environmental, economic, and health benefits.

2.5.2. Mechanical control

Apart from the fact that mechanical control is more labour intensive and needs much time, it gives quick results. Some of the common mechanical crop protection measures include: handpicking of large larvae or adults; imposing of mechanical barriers; removal of crop stubbles and other unwanted plants prior to, during or after the cropping season (also termed sanitation); and denying pests alternative hosts. An experiment to this effect was conducted in which a combination of barrier and sanitation was utilized to minimize BSFB damage to brinjal plants. The highest marketable fruit yield and as well as lowest fruit infestation in terms of number and weight was obtained from use of barrier with clipping practices rather than by the use of barrier alone, though later one is the best for farmers practice in small scale production (Ghimire 2001). Due to the small size of sucking pests and their position in lower side of leaves, its very difficult to control them by mechanical means.

2.5.3. Sex pheromone traps

In case of non-Bt brinjal, pheromone is the another best one to practice managing the BSFB. The sex pheromone works by confusing the male adult for mating and thus prevents fertilized egg production by trapping large number of male moths, which results in reduction of larval and adult population development (Rahman 2006). Among different types of pheromone traps, water trap is the most preferred one, placed at crop canopy level which caught significantly more male moths than placed 0.5 m above the canopy (Cork *et al*. 2003). He concluded that the sex pheromone was potential component in the IPM program. Delta traps and funnel traps are useful for the adult luring by the sex pheromone in the field conditions.

2.5.4. Biological control

Among different biological control measures against pest complex of brinjal *Passilomyces fumosoresus* @ 1l/ha was recorded lowest population of all the pests recorded with highest yield (85.06 q / ha) (Satyendra 2013). The best-known virus of insect is the *Nuclear Polyhedrosis Viruses* (NPV). Gupta and Rosan (1995) reported that under field condition, insect pests even lepidopteran larvae are very sensitive to NPV. However, Ghimire (2001) reported that the efficacy NPV against *L. orbonalis* is lower but it can be used as one of the important options of management. A report from Sri Lanka indicates that the occurrence of a larval parasitoid, *Trathala flavo-orbitalis* (Cameron) (Hymenoptera: Ichneumonidae), which has potentiality of pest control (Sandanayaka and Edirisinghe 1992). This parasitoid has been reported to be present in and Bangladesh (Alam and Sana 1964); however, its contribution to pest control was rarely documented and does not appear to be significant. Since, biological control is an important component in IPM and very little information is available on the role of biological control agents in combating BSFB in the region. There is also significant relationship between incidence of *L. orbonalis* in terms of shoot infestation and with coccinellids and spiders (Singh *et al.* 2009). Sucking pests of brinjal and other vegetables have showed susceptibility to any biocontrol agents. Microbial pathogens especially fungal pathogens such as *Beauveria bassiana*, *Metarhizium anisopliae* and *Verticillium lecanii* have been experimented for a wide range of sucking pests. Naik and Shekharappa (2008) carried out an experiment on some microbial fungal pathogens. They reported 96.67% mortality of leafhoppers at 10 DAT with *B. bassiana* and *M. anisopliae*. However, *Verticillum lecanii* oil and *B.bassiana* WP formulations recorded 93.33% mortality. The efficacy against aphids revealed that *V. lecanii* oil-based formulation showed 100% mortality followed by *V. lecanii* WP (96.67%) and B. bassiana oil and WP formulations (93.33%). *V. lecanii* oil based formulation recorded the 97.00% mortality of thrips followed by *V.lecanii* WP and *B. bassiana* oil and WP and *M. anisopliae* oil (93.33%). *Metarhizium anisopliae* are used as biological control agents of insects including gregarious insect pests (Moorhouse *et al*. 1993). Khalil *et al.* (1985) evaluated the fungus *V. lecanii* against *A. gossypii* (Glover) in Czechoslovakia. A blastospore suspension of fungus with a concentration of 10^8 spores per ml was sprayed to control cotton aphid. The larvae of *Chrysoperla carnia* are predacious, feeding on the eggs and neonates of lepidopterous larvae, nymphs and adults of whitefly, aphids thrips, scale insect, mealy bugs and mites. It has great potential as bioagent against citrus aphids, whiteflies, citrus psylids and citrus mealy bugs (Balasubramani and Swamiappan 1994).

2.5.5. Chemical control

Management of insect pests in Bangladesh is mainly chemical dependant; in many cases, farmers rely solely on insecticides to get rid of pest problems. A wide range of pesticides from diverse genre are available in commercial forms. Many pesticidal trials have been done previously by researchers to check the efficacy of those chemicals and susceptibility of various inset pests to them. Many promising insecticides have been invented recently.

Spinosad is one of such new chemicals which is derived from fermentation broth of soil actinomycetes, *Saccharopolyspora spinosa*, containing a naturally occurring mixture of spinosyn A and spinosyn D. It is not hazardous to the nymphs and adults of the natural enemies. Spinosad has been registered in over 30 countries for the control of lepidoptera, coleoptera, diptera and thysonaptera (Williams *et al.* 2004). Yousafi *et al*. (2015) reported that Spinosad (Tracer 240SC) proved to be the most effective insecticide to control fruit infestation. A trial experiment was carried out by Patra *et al.* (2009) on the efficacy of Spinosad on BSFB. Results revealed that spinosad was the most effective against BSFB. Rani *et al.* (2005) reported that spinosad effectively protected the cotton crop with minimum incidence of spotted boll worm. Chowdhury *et al.* (1993) in their experiment stated that Spinosad was more effective in controlling BSFB and less effective in controlling sucking pests of brinjal.

Chloronicotinyls or neonicotinoids are newly introduced group of novel insecticides which act on receptor protein of insect nervous system and highly effective against sucking pests. Their selectivity, lower dose and relative safety to non-target organism make this group an ideal component in integrated pest management (IPM) resulting in less insecticidal load in the environment (Ghoshal and Chatterjee 2013). Imidacloprid is less toxic to the environment as it required to spray in little amounts. (Wing *et al.* 2000, 1998). Kumar *et al*. (2017) carried out an experiment to compare efficacy of some promising insecticides. The maximum reduction jassid population was recorded in the Imidacloprid (61.04) followed by fipronil (58.49) and emamectin benzoate (57.01) treated plots as well as the maximum reduction per cent of aphid population was recorded in the treatment with imidacloprid (62.10) followed by fipronil (59.34) and emamectin benzoate (57.30). Misra (2005), Knaust and Poehling (1994) carried out separate experiments in different locality. They found imidacloprid as most effective to control aphids, jassids and whitefly. Ameta and Sharma (2005) evaluated imidacloprid against sucking pests of cotton and found as most effective in controlling them. An experiment was done by Mhaske and Mote (2005) for controlling insect pest complex of brinjal. They found imidacloprid to be the most effective in controlling sap sucking pests of brinjal.

Malathion is a synthetic chemical insecticide that has been manufactured in the U.S. and is being used since 1950. It is a colourless to amber liquid with a garlic or skunk like odour that is used to control a wide range of insects that infest vegetable plants. Malathion is the most overused insecticide and his insecticide has been used so indiscriminately that many major pests have been developed resistance against it. A research was carried out by Singh *et al.* (2008) to check the efficacy of malathion and some other insecticides. Three insecticides i.e. Endosulfan (0.05%), Cypermethrin (0.05%) and Malathion (0.05%) were sprayed against the infestation of shoot and fruit borer to evaluate suitable control measure against the pest to get the higher yield. The minimum (21.5%) infestation was observed with Endosulfan followed by Cypermethrin (24.13%) and Malathion (25.17%). That implies the lowest efficacy of malathion against BSFB.

Due to its high nutritional value and increasing demand, brinjal cultivation in Bangladesh needs special attention. Many minor pests have emerged as major pests and even gained the key pest status recently. Unwise and indiscriminate application of pesticides not only degrading the ecological balance but also disrupting the pest behaviour. To get acquainted with new challenges of global climate change, sound knowledge of nature of damage, seasonal abundance as well as succession of insect pest complex and mode of action of insecticides are necessary.

CHAPTER III

MATERIALS AND METHODS

The present investigation entitled “Comparing incidence and infestation of insect pests in Bt and non-Bt brinjal and their chemical management” was carried out in the experimental field of Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka-1207, Bangladesh during rabi season 2017-2018. The present chapter deals with the material used and methods required. Materials and methods include location of experiment, soil and climate condition of the experimental plot, materials used, design of the experiment, data collection and data analysis procedure that followed in this experiment has been presented under the following headings:

3.1. Description of the experimental site

3.1.1. Geographical location and climate

The experiment was conducted during the period from October 2017 to April 2018.The present piece of research work was conducted in the experimental area of Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka-1207, Bangladesh. The location of the site is $23^{0}74$/N latitude and $90^{0}035$/E longitude with an elevation of 8.2 meter from sea level. The geographical location of the experimental site was under the subtropical climate and its climatic conditions is characterized by heavy scanty rainfall during the rabi season. The soil belonged to “The Modhupur Tract”, AEZ-28 (FAO 1988). The experimental area was flat having available irrigation and drainage system and above flood level.

3.2. Weather condition during the crop season

Details of meteorological data in respect of average maximum temperature, minimum temperature, rainfall and relative humidity during course of studies i.e. from 45th SW to 14th SW has been presented in figure 3.

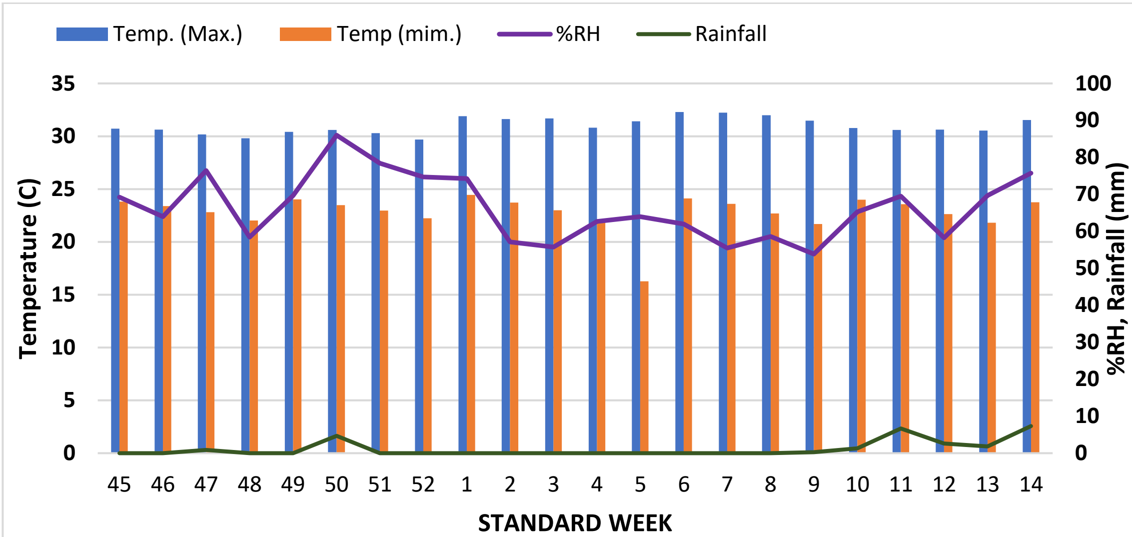

Figure 3. Weather data (average) during the standard weeks of the experiment.
Source: Bangladesh Meteorological Department 2018

3.3. Planting materials

BARI Bt Begun 2 (Bt Kajla) and BARI Begun 4 (Kajla) were used as the test crop in this experiment. Seeds were collected from BARI (Bangladesh Agricultural Research Institute), Gazipur, Bangladesh.

3.4. Treatments of the experiment

Being a two-factor experiment, present study consists two factors such as variety and insecticide doses. Details of treatments are given below:

Table 1. Treatments used in the experiment

Factor	Level	Name	Dose/ha
V	1	BARI Bt Begun-2(Bt Kajla	
V	2	BARI Begun-4 (Kajla)	
T	1	Absolute	Control
T	2	Imidacloprid	Admire 20SL@ 0.5 mlL^{-1} water
T	3	Spinosad	Tracer 45 SC@ 0.4 mlL^{-1} water
T	4	Malathion	Faythion 57 EC@2mlL^{-1} water

3.5. Experimental design and layout

The experiment was laid out in a factorial randomized complete block design (RCBD) with four replications, where the experimental area was divided into four blocks representing the replications to reduce soil hetero-genetic effects. Each block was divided into eight-unit plots as treatments demarked with raised bunds. Thus, the total numbers of plots were 32. The unit plot size was 3.6 m × 1.6 m. The distance maintained between two blocks and two plots were 0.5 m and 0.5 m, respectively.

3.6. Land preparation and intercultural operation

Both varieties were sown on September 30, 2017. The plot selected for conducting the experiment was opened in the 3rd week of October 2017 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 good tilth condition. Organic and inorganic manures as indicated below were mixed with the soil of each unit plot. Seedlings were transplanted on October 25, 2017. Irrigation (9 times) and drainage were provided when required. Weeding (5 times) was done to keep the plots free from weeds, which ultimately ensured better growth and development.

3.7. Fertilizers and manure application

The fertilizers N, P, K in the form of Urea, TSP, MoP respectively and S, Zn and B in the form of Gypsum, Zinc sulphate and Borax were applied as per recommendation of Bangladesh Agricultural Research Institute (Mondal *et al.* 2011). Urea was applied as granule. The entire amount of TSP, MP, gypsum, zinc sulphate and borax were applied during the final preparation of land. The Urea was applied in four equal installments at Basal, 30 DAT, flowering and fruit setting.

Table 2: Manure and fertilizers applied during experimental period

Manure/Fertilizer	Doses (kg/ha)			
	Basal	**15 DAT**	**Flowering**	**Fruit setting**
Cow dung	10000			
Urea	60	60	60	60
TSP	250			
MP	200			
Gypsum	100			
Boric acid	10			

Mondal *et al.* 2011

3.8. Treatment application method, time and instrument

Treatments were sprayed 5 times on January 24, February 08, February 22, march 7 and march 21 of 2018 with the help of knapsack sprayer.

3.9. Data recording

3.9.1. To study pest incidence in Bt and non-Bt brinjal varieties

Regular observations were made immediately after transplantation of plants once in a standard week to record different insects of brinjal. The insects appearing on the crop right from transplantation up to harvest were recorded. The unprotected crops (absolute treatment) were used for this purpose. The sequence in which the insects appeared was also noted. For observations, 5 plants from each plot were randomly selected and thus, 20 plants for each variety were selected and population of different insect pests and natural enemies thereon was assessed. Observations on different insect pests were recorded as detailed below:

3.9.1.1. Shoot and fruit borer

Observation on intensity of infestation of shoot and fruit borer were recorded as follows:

3.9.1.1.1. Shoot infestation

Soon after noticing the *L. orbonalis* infestation, the shoot infestation was judged by counting healthy plants and plants having shoots infested by shoot and fruit borer of 5 randomly selected plants per plot from four replications. After each observation, damage shoots were removed.

3.9.1.1.2. Fruit infestation

Similarly, fruit infestation by *L. orbonalis* was judged by counting the number of total healthy fruits and fruits damaged by shoot and fruit borer at each picking per plot. After each observation damage fruits were recorded and percent shoot and fruit infestation were calculated.

$$\%\, Shoot\ or\ fruit\ infestation = \frac{Number\ of\ shoots\ or\ fruits\ damaged}{Total\ number\ of\ shoots\ or\ fruits\ observed}\, x\, 100$$

3.9.1.2. Epilachna beetle

Number of damaged leaves/ five plants were observed to record data for epilachna beetle.

3.9.1.3. Jassid

The number of nymphs and adults of leafhopper, *Amrasca devastans* were counted on six leaves (each from 2 upper, middle and lower leaves per plant) by examining each leaf carefully during early morning hours, when the pest was less active. To begin with, leafhoppers on upper surface of the leaves were counted and then the leaf was tilted carefully to count population on the lower surface (Ramrao 2012).

3.9.1.4. Aphid and Whitefly

Six leaves (each from 2 upper, middle and lower per plant) were carefully examined for the presence of nymph and adults of aphids and whitefly.

3.9.2. To study the efficacy of insecticides against pest complex of Bt and non-Bt brinjals

3.9.2.1. Method of observation for brinjal shoot and fruit borer (BSFB)

Observations on shoot and fruit borer, *L. orbonalis* were recorded on 5 randomly selected tagged plants/plot. Before fruiting stage, pre-treatment observations on shoot infestation were recorded 24 hours before spraying, while post-treatment observations were taken 7 and 14 days (Sharma 2012) after application of the treatments.

Fruit infestation by shoot and fruit borer was assessed by counting the number of total damage and healthy fruits at each picking per plot and percentage fruit infestation was calculated.

3.9.2.2. Epilachna beetle

Total number of epilachna beetle found in five randomly selected plants were recorded in each plot after 7 days and 14 days of spraying. Then the average number of epilachna beetle were recorded.

3.9.2.3. Sucking pests

Upper surface of the leaves was counted and then the leaf was tilted carefully to count population on the lower surface. Six leaves per plant and five pants from each plot were observed during 7 days ad 14 days after insecticide application. The average number were put in statistical package.

3.10. Data analysis

Recorded data were put and compiled on MS excel spreadsheet. Later on, data were analyzed by using STATISTICS 10 software for analysis of variance. ANOVA was made by F variance test and the mean value comparisons were performed by Tukey's test.

CHAPTER IV

RESULTS AND DISCUSSION

The results of the studies conducted on the "Comparing incidence and infestation of insect pest in Bt and non-Bt brinjal and their chemical management" are depicted in this section.

4.1. Documentation of insect pests and their natural enemies in brinjal field during the study period

4.1.1. Insect pests infesting brinjal

Eight pests (Table 3) namely the brinjal shoot and fruit borer (*Leucinodes orbonalis* Guen., Family: Pyralidae), epilachna beetle (*Epilachna dodecastigma* Wied., Family: Coccinellidae), jassid (*Amrasca biguttula biguttula* Ishida, Family: Cicadellidae), aphid (*Aphis gossypii* Glover, Family: Aphidae), whitefly (*Bemisia tabaci* Genn., Family: Aleyrodidae), mealy bug (*Coccidohystrix insolita* G., Family: Pseudococcidae), mite (*Tetranychus* sp. Family: Tetranychidae), green leafhopper (*Nephotettix virescens*, Family: Cicadellidae) and three natural enemies namely coccinellids viz. lady bird beetle (*Cheilomenes* sp., Family: Coccinellidae), spider (*Argiope luzona* Walckenaer, Family: Argiopidae) and lace wing (*Chrysoperla carnea*, Famiy: Chrysopidae) were recorded in the experimental site. Among the pests, brinjal shoot and fruit borer as well as epilachna beetle are chewing pests and rest of all are sucking pests of brinjal. However, all insects except BSFB are leaf dwelling insects but BSFB bore into the shoot and fruit at vegetative and fruiting stage respectively. All the natural enemies are predacious in nature. Similar results were obtained by Chandrakumar *et al.* (2008) as they reported 9 insect pests and natural enemy in rabi season. Lower number of insect pests in rabi season may be attributed to the lower temperature and relative humidity that is uncomfortable for maximum pests.

Table 3. Lists of insect pests and their natural enemies found in the experimental site

Name of the insect	Scientific name	Family	Order	Habitat	Status
Brinjal shoot and fruit borer	*Leucinodes orbonalis* (Guen.)	Pyralidae	Lepidoptera	Shoot and fruit	Pest
Epilachna beetle	*Epilachna dodecastigma*(Wied.)	Coccinellidae	Coleoptera	Leaf	Pest
Jassid	*Amrasca biguttula biguttula* (Ishida)	Cicadellidae	Homoptera	Leaf	Pest
Aphid	*Aphis gossypii* (Glover)	Aphidae	Homoptera	Leaf	Pest
Whitefly	*Bemisia tabaci* (Genn.)	Aleyrodidae	Homoptera	Leaf	Pest
Mealy bug	*Coccidohystrix insolita G.*	Pseudococcidae	Homoptera	Leaf	Pest
Mite	*Tetranychus* sp.	Tetranychidae	Acarina	Leaf	Pest
Green leafhopper	*Nephotettix virescens*	Cicadellidae	Homoptera	Leaf	Pest
Coccinellids (lady bird beetle)	*Cheilomenes* sp.	Coccinellidae	Coleoptera	Leaf	Natural enemy
Spider	*Argiope luzona* (Walckenaer)	Argiopidae	Acarina	Leaf	Natural enemy
Lace wing	*Chrysoperla carnea*	Chrysopidae	Neuroptera	leaf, shoot	Natural enemy

4.2. Comparing incidence of insect pests in Bt and non-Bt brinjal

4.2.1. Comparing the incidence of Jassids in Bt and non-Bt brinjals

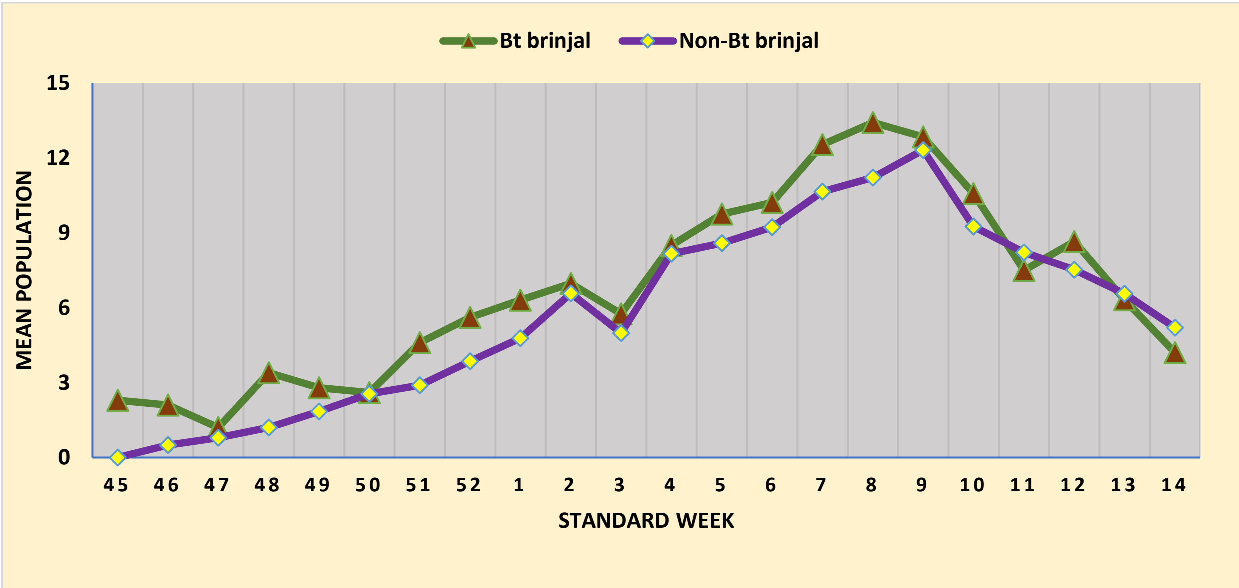

Figure 4. Comparing incidence of jassid in Bt and non-Bt brinjal

Present study reveals that Jassid was present throughout the cropping season of brinjal and remain available upto the crop maturity stage (Figure 4). The number of jassids (nymph and adult) were recorded as weekly average per six leaves. In case of Bt brinjal, jassids were found from the first week (first week of November, 2017 i.e. 45th standard week) to the last week (first week of April, 2018 i.e. 14th standard week) of the growing period while, there was no jassid observed on the first week in non-Bt brinjal. Bt brinjal experienced a decreasing population in first three week and reached at its lowest population (1.2 jassids/ six leaves) and then started increasing in number from the 47th standard week. However, there was a gradual soaring in case of non-Bt brinjal. Jassid population in Bt brinjal reached at its first peak (3.4 jassids/ six leaves) during 48th SW whereas, first peak of non-Bt brinjal occurred on the 2nd SW. Thereafter, both varieties experienced increasing population. Jassid in Bt brinjal reached its final peak (13.42 jassids/ six leaves) during 8th SW and 12.32 jassids/ five plants in non-Bt brinjal during 9th SW. Then both varieties experienced gradual decrease upto the end of season. However, average number of jassids were less in non-Bt brinjal than Bt except the last three standard weeks. In the present study, conformity is shown with the study of Birla (2011), Prasad and Logiswaran (1997b) as they reported peak jassid population at the later stage of cropping season. Favorable weather parameters can be attributed for the higher population in this period. However, higher number of jassids in Bt brinjal than non-Bt could be due to negligible shoot and fruit infestation by BSFB (Jeyakumar *et al*. 2008).

4.2.2. Comparing incidence of aphid in Bt and non-Bt brinjal

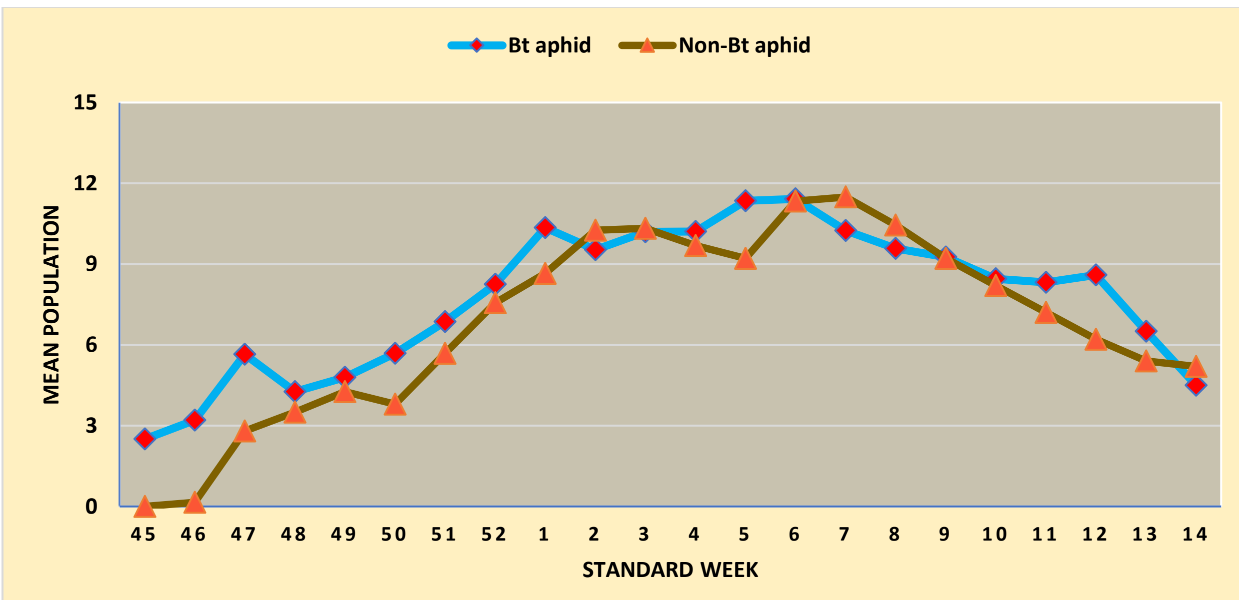

Figure 5. Comparing incidence of aphid in Bt and non-Bt brinjal

From figure 5 it is shwed that aphid was present throughout the growing season of brinjal and remain available upto the end of the harvesting. The number of aphid (nymph and adult) were counted as weekly average per six leaves. In case of Bt brinjal, aphids were found from the first week (first week of November, 2017 i.e. 45^{th} standard week) to the last week (first week of April, 2018 i.e. 14^{th} standard week) of the growing period while, no aphid observed on the respective week in non-Bt brinjal. Starting from the lowest population (2.5 aphids/ six leaves) Bt brinjal experienced a first peak (5.65 aphids/ six leaves) of aphid population in 47th SW and then started increasing in number from the 49th standard week. However, there was a gradual soaring in case of non-Bt brinjal. Aphid population in Bt brinjal reached at its first peak (4.26 aphids/ six leaves) during 49th SW. Thereafter, both varieties experienced increasing population. During the vegetative stage, highest number (10.35 aphids/ six leaves) of aphid in Bt brinjal found in 1st SW and 10.33 aphids/ six leaves in non-Bt brinjal during 3rd SW. Aphid in Bt brinjal reached its final peak (11.42 aphids/ six leaves) during fruiting stage at 6th SW while non-Bt brinjal experienced 11.49 aphids/ six leaves at its fruiting stage during the fruiting stage as the highest population. Thereafter, both varieties experienced gradual decrease upto the end of season. However, average number of aphids were less in non-Bt brinjal than Bt except the 7th, 8th and the 14th standard weeks. Findings shows (fig. 2) that peak population of aphid in both varieties found between February and March. This result is in accordance with the findings of Shakeel *et al.* (2014) and Chandrakumar *et al.* (2008). Maximum temperature of 32.3°C–31.7°C and a favorable relative humidity during that period favoured the multiplication of aphids. Possible reason behind the higher aphid population in Bt brinjal may be due to the host-plant interaction or different chemical constituents that made the Bt variety susceptible (Faria *et al.* 2007).

4.2.3. Comparing incidence of whitefly in Bt and non-Bt brinjal

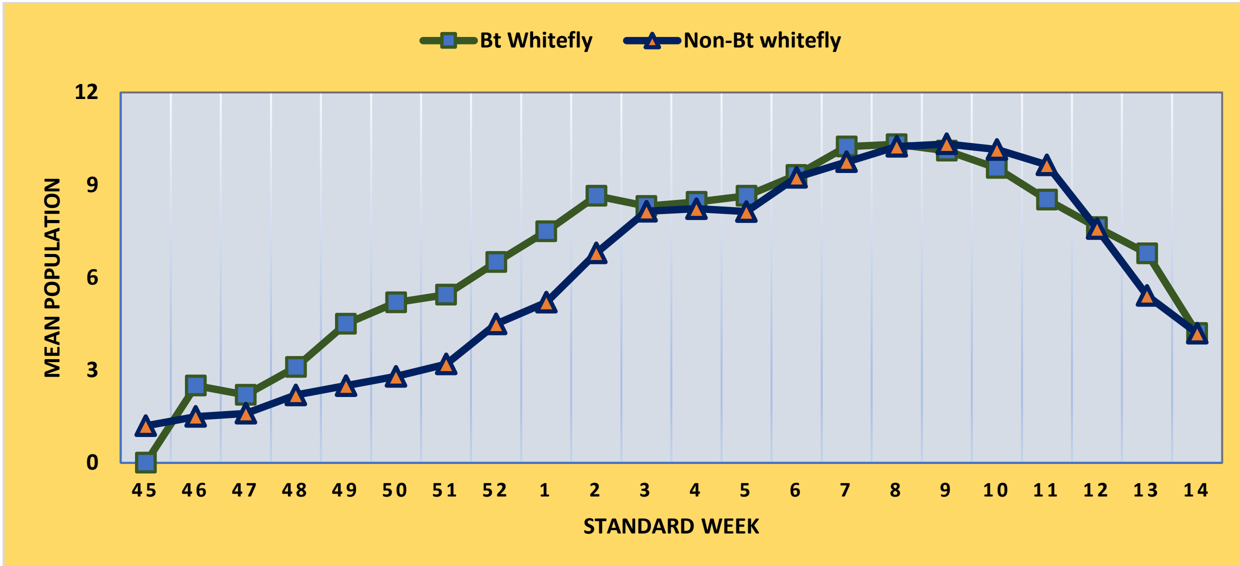

Figure 6. Comparing incidence of whitefly in Bt and non-Bt brinjal

Study shows (Figure. 6) that Whitefly was present throughout the growing season of brinjal and remain available upto the end of the harvesting. The number of whitefly (nymph and adult) were counted as weekly average per six leaves. In case of Bt brinjal, whiteflies were found from the second week (second week of November, 2017 i.e. 46th standard week) to the last week (first week of April, 2018 i.e. 14th standard week) of the growing period while, whitefly was found in non-Bt brinjal from the very first week of data recording. Starting from the zero population Bt brinjal experienced a first peak (2.5 whiteflies/ six leaves) of whitefly population in 46th SW and then started increasing in number from the 48th standard week. However, there was a gradual soaring in case of non-Bt brinjal. Whitefly population in Bt brinjal reached at its second peak (8.65 whiteflies/ six leaves) during 2nd SW. Thereafter, both varieties experienced increasing population. During the vegetative stage, highest number (8.65 whiteflies/ six leaves) of whitefly in Bt brinjal found in 1st SW and 8.23 whiteflies/ six leaves in non-Bt brinjal during 8th SW. Whitefly in Bt brinjal reached its final peak (10.32 whiteflies/ six leaves) during fruiting stage at 8th SW while non-Bt brinjal experienced 10.33 whiteflies/ six leaves at its fruiting stage during the 9th SW as the highest population. Thereafter, both varieties experienced gradual decrease upto the end of season. However, average number of whiteflies were less in non-Bt brinjal than Bt except the 9th, 10th and the 11th standard weeks. Present findings can be attributed to favorable temperature and other related weather parameters and endorsed by the findings of Marabi *et al.* (2017) and Mathur *et al.* (2012).

4.2.4. Comparing incidence of epilachna beetle in Bt and non-Bt brinjal

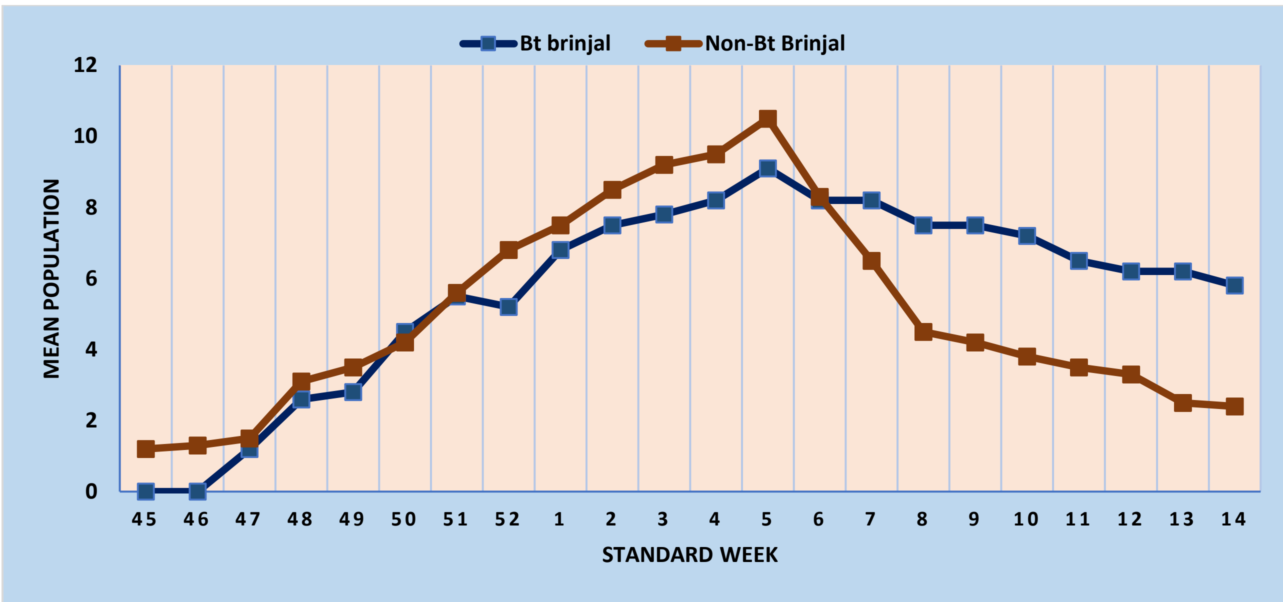

Figure 7. Comparing incidence of epilachna beetle in Bt and non-Bt brinjal

Study shows that epilachna beetle was present in non-Bt brinjal throughout the cropping season whereas, it is the 47th SW when Bt brinjal has been attacked first by epilachna beetle (Figure 7). The number of epilachna (grub and adult) were counted as weekly percent damaged per leaf. Starting from the zero population Bt brinjal experienced a first peak (2.5 percent damage/ six leaves) of epilachna beetle population in 47th SW and then started increasing in number gradually. However, there was a gradual increase in case of non-Bt brinjal and first peak (3.1 percent damage/ six leaves) occurred in 48th SW. Epilachna beetle population in Bt brinjal reached at its highest peak (8.65 percent damage/ six leaves) during 5th SW, similarly in case of non-Bt, the highest (10.5 percent damage/ six leaves) peak was during the same week. Afterward, both varieties experienced a decline in population, however, the rate was more prominent in non-Bt. It has been seen that during the vegetative stage, epilachna population was higher in non-Bt brinjal than that of Bt, but in case of fruiting stage, the damage percentage was higher in Bt than that of non-Bt. Due to the presence of sufficient food source during the initial cropping season epilachna population increased rapidly but as the competition became more intense, population density decreased. Hirano (1995) reported similar findings. Bt brinjal experienced lower epilachna infestation than non-Bt. That might be due to the fact that Bt was already highly infested by sucking pests and that in turn reduced the choice of epilachna beetle.

4.2.5. Comparing incidence of shoot and fruit borer in Bt and non-Bt brinjal

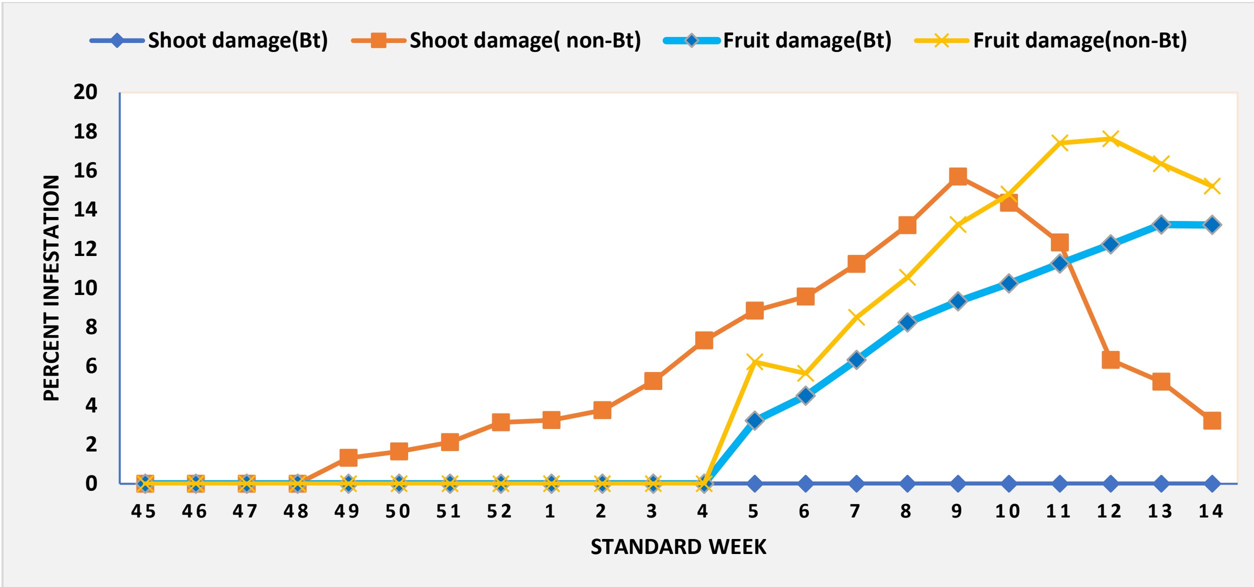

Figure 8. Comparing incidence of shoot and fruit borer in Bt and non-Bt brinjal

Findings reveals that shoots of non-Bt brinjal were infested throughout the growing season of brinjal and remain available upto the maturity stage whereas, no shoot infestation has been recorded in Bt brinjal (Figure 8). However, shoot infestation in non-Bt variety started from the 49th SW and then gradually increased up to 9th SW. The highest shoot infestation (15.69%) was found in non-Bt brinjal during 9th SW. With the commencing of fruiting stage, intensity of shoot infestation declined and the rate of declining was steady up to the end of the season. Surprisingly, Bt brinjal has been found to be infested by BSFB in the fruiting stage. Starting from the traces, Bt brinjal experienced highest infestation (11.5%) during 13th SW. Whereas, a significant amount of fruit infestation has been recorded in case of non-Bt brinjal. Starting from the 4th SW, infestation reached its first peak (6.23%) at 5th SW and then gradually increased up to 12th SW. The highest fruit infestation (17.63%) was found from 12th SW and subsequently the intensity lessened according to maturity stage. Lower than usual temperature, negligible rainfall may be the reason behind lower shoot infestation by BSFB. But later on, as the weather became more comfortable, shoot and fruit infestation intensified. These findings collaborate with the findings of Lodhi (2005), Mahesh and Men (2007a), Ghosh and Senapati (2009). They also reported that the average temperature 21.4 to 31.80C, average relative humidity 35 to 86% have been found congenial for the multiplication and development of BSFB. However, it is not clear how the Bt brinjal was infested by BSFB. Previous record of breaking resistance of Bt cotton by pink bollworm suggests that flowering period of this trial coincided with the peak activity of BSFB (Kranthi 2015). And BSFB may break resistance of both Cry1Ac and Cry2Ab with new biotype.

4.3. Efficacy of treatments on infestation of insect pests of brinjal

4.3.1. Efficacy of treatments on infestation of jassid

Different varieties behave differently to different insect pests. When some varieties are exposed to same environment and management system, their interaction with different insect pests vary mainly for their different genetic makeup. The results (table 4) showed that jassid infestation is low in V_2 which was 7.33 and 11.65 in number at vegetative stage and fruiting stage respectively. On the other hand, it was high in V_1 which was 7.58 and 12.51 in number at vegetative and fruiting stage respectively.

Different insecticides interfere differently with the insect-host interaction system. The results showed that the jassid infestation was lowest for treatment T_2 (6.41 and 10.8 in number at vegetative and fruiting stage respectively) and it was highest for T_1 (8.26 and 13.22 in number at vegetative and fruiting stage respectively).

Interaction effect of variety and different type of insecticides affected jassid which was infestation not statistically significant but numerically; under the present study (Table 4). Different treatment combination viewed different number of jassid attacked the brinjal plants at vegetative and fruiting stage. It was evident that the number of jassid was lowest in V_2T_2 which was 6.33 at vegetative stage, statistically identical with V_1T_2 (6.50) and 10.31 at fruiting stage. On the other hand, the highest number of jassid was recorded in V_1T_1 which was 8.39 and 13.49 at vegetative and fruiting stages respectively. Higher BSFB infestation and chewing pest density may lower the sucking pest population in non-Bt brinjal. Maximum efficacy of imidacloprid in this trial is confirmed by the findings of Kumar *et al.* (2017), Ameta and Sharma (2005) as well as Mhaske and Mote (2005). All researchers have found imidacloprid as the best insecticide to control jassids. Due to its highly systemic functional response, imidacloprid might show the best results.

Table 4: Effect of variety, insecticides and their interactions on infestation of jassid during rabi season (from September 2017 to April 2018)

Treatments	No. of jassid (Vegetative stage)	No. of jassid (Fruiting stage)
Effect of Variety		
V_1	7.58 a	12.51 a
V_2	7.33 b	11.65 b
$T_{0.05}$	6.070	10.798
Effect of insecticides		
T_1	8.26 a	13.22 a
T_2	6.41 d	10.8 d
T_3	7.30 c	11.79 c
T_4	7.82 b	12.5 b
$LSD_{0.05}$	0.264	0.289
Interaction effect of variety and insecticides		
V_1T_1	8.39 a	13.49 a
V_2T_1	8.13 b	12.95 b
V_1T_2	6.50 f	11.29 d
V_2T_2	6.33 f	10.31 e
V_1T_3	7.45 d	12.19 c
V_2T_3	7.17 e	11.38 d
V_1T_4	7.94 b	13.05 b
V_2T_4	7.70 c	11.96 c
$LSD_{0.05}$	0.3218	0.2663
CV (%)	4.11	3.50

V_1= BARI Bt brinjal 2 (Bt Kajla), V_2= BARI brinjal 4 (Kajla), T_1= Untreated (control), T_2= Imidacloprid, T_3= Spinosad, T_4= Malathion.
In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

4.3.2. Efficacy of treatments on infestation of aphid

Infestation of aphid showed varied results on different varieties in the present study (Table 5). The number of aphids attacked brinjal plants was lowest in V_1 which was 9.28 at vegetative stage and 9.89 at fruiting stage which was statistically similar to V_2 (9.17) at fruiting stage. On the contrary, it was observed highest number of aphid (9.59) in V_2 at vegetative stage.

Effect of insecticides was recorded in the same environmental and management condition. It was evident that the lowest number of aphids was 8.22 and 8.83 at vegetative and fruiting stage respectively in treatment T_2. On the other hand, it was highest in T_1 which was 10.58 and 11.30 at vegetative and fruiting stage respectively. Interaction effect of variety and different type of insecticides affected aphid infestation significantly under the present study (Table 5). Different treatment combination viewed different number of aphids attacked the brinjal plants at vegetative and fruiting stage. The result showed that the number of aphids was lowest in V_2T_2 which was 8.14 at vegetative stage (statistically identical with V_1T_2 of 8.29) and 8.40 at fruiting stage. On the other hand, the highest number of aphids was recorded in V_1T_1 which was 10.45 at vegetative stage (statistically identical to V_2T_1 of 10.71) and 11.48 at fruiting stage. Our study endorsed by the results of Nag *et al.* (2017), Gavkare *et al.* (2013) and Hossain *et al.* (2013).

Table 5: Effect of variety, insecticides and their interactions on infestation of aphid during rabi season (from September 2017 to April 2018)

Treatments	No. of Aphid (Vegetative stage)	No. of Aphid (Fruiting stage)
Effect of Variety		
V_1	9.28 a	9.89 a
V_2	9.59 a	9.17 a
$T_{0.05}$	-2.961	-0.407
Effect of insecticides		
T_1	10.58 a	11.30 a
T_2	8.22 d	8.83 d
T_3	9.16 c	9.16 c
T_4	9.79 b	10.42 b
$LSD_{0.05}$	0.281	0.23
Interaction effect of variety and insecticides		
V_1T_1	10.45 a	11.48 a
V_2T_1	10.71 a	11.12 b
V_1T_2	8.29 e	9.27 e
V_2T_2	8.14 e	8.40 g
V_1T_3	8.98 d	8.78 f
V_2T_3	9.33 c	9.54 e
V_1T_4	9.41 c	10.02 d
V_2T_4	10.18 b	10.82 c
$LSD_{0.05}$	0.356	0.29
CV (%)	4.33	6.25

V_1= BARI Bt brinjal 2 (Bt Kajla), V_2= BARI brinjal 4 (Kajla), T_1= Untreated (control), T_2= Imidacloprid, T_3= Spinosad, T_4= Malathion.

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

4.3.3. Efficacy of treatments on infestation of whitefly

The present study showed lowest number of whitefly recorded in V_2 which was 7.02 and 9.31 at vegetative and fruiting stage respectively. The highest number was recorded in V_1 which was 7.62 and 9.53 respectively.

Among the insecticidal treatments, T_2 showed the highest effectivity because it showed the lowest number of whitefly which was 6.52 and 8.45 at vegetative and fruiting stage respectively. The highest number of whitefly was recorded in T_1 which was 8.26 and 10.27 at vegetative and fruiting stage respectively. Combined treatment of varieties and insecticides affect white fly infestation significantly under present study (Table 6). Different treatment combination viewed different number of whitefly attacked the brinjal plants at vegetative and fruiting stage. The lowest number of whitefly was recorded in V_2T_2 which was 6.16 and 8.31 at vegetative and fruiting stage respectively. On the other hand, the highest white fly infestation was recorded in V_1T_1 which was 8.42 in number at vegetative stage and 10.37 at fruiting stage (statistically similar to V_2T_1 of 10.16 at fruiting stage). Efficacy of imidacloprid in controlling whitefly is previously confirmed by Ghosal and Chatterjee (2013), Castle and Palumbo (2006), Misra and Senapati (2003). Nath and Sinha (2011) also reported that neonicotinoids could be used effectively in controlling the sucking pests population including whitefly.

Table 6: Effect of variety, insecticides and their interactions on infestation of whitefly during rabi season (from September 2017 to April 2018)

Treatments	No. of Whitefly (Vegetative stage)	No. of Whitefly (Fruiting stage)
Effect of Variety		
V_1	7.62 a	9.53 a
V_2	7.02 b	9.31 b
$T_{0.05}$	8.526	5.354
Effect of insecticides		
T_1	8.26 a	10.27 a
T_2	6.52 d	8.45 d
T_3	6.98 c	9.17 c
T_4	7.51 b	9.82 b
$LSD_{0.05}$	0.541	0.591
Interaction effect of variety and insecticides		
V_1T_1	8.42 a	10.37 a
V_2T_1	8.11 b	10.16 a
V_1T_2	6.87 de	8.57 d
V_2T_2	6.16 f	8.31 e
V_1T_3	7.23 c	9.28 c
V_2T_3	6.74 e	9.067 c
V_1T_4	7.94 b	9.905 b
V_2T_4	7.07 cd	9.720 b
$LSD_{0.05}$	0.28	0.225
CV (%)	6.62	5.20

V_1= BARI Bt brinjal 2 (Bt Kajla), V_2= BARI brinjal 4 (Kajla), T_1= Untreated (control), T_2= Imidacloprid, T_3= Spinosad, T_4= Malathion.
In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

4.3.4. Efficacy of treatments on infestation of epilachna beetle

Different varieties respond differently to epilachna beetle infestation in the present study (Table 4). The lowest infestation was recorded in V_1 (3.27 and 3.70 in number at vegetative and fruiting stage respectively). V_2 (3.58) showed statistically identical result to V_1 (3.70) at fruiting stage.

In case of insecticidal treatments, T_3 with the number of epilachna beetle of 1.72 and 1.31 at vegetative and fruiting stage respectively was recorded the lowest whereas the highest number of epilachna beetle was recorded in T_1 (4.78 and 5.84 at vegetative and fruiting stage respectively). In case of interaction of combined treatments of varieties and insecticides revealed a significant result in the present study in table 7. The lowest number of epilachna beetle was recorded in V_1T_3 (1.25 and 1.31 at vegetative and fruiting stage respectively). V_1T_3 (1.31) and V_2T_3 (1.30) showed statistically similar result in case of fruiting stage. It is revealed that variety had no impact on the density of epilachna population. However, Spinosad performed better than other insecticides to control epilachna beetle. However, present study doesn't show conformity with the study of Sharma and Kaushik (2010). They found Spinosad less effective in controlling epilachna beetle. However, it needs further trial to check the efficacy of Spinosad against epilachna beetle.

Table 7: Effect of variety, insecticides and their interactions on infestation of epilachna beetle in brinjal field during rabi season (from September 2017 to April 2018)

Treatments	No. of epilachna (Vegetative stage)	No. of epilachna (Fruiting stage)
Effect of Variety		
V_1	3.266 a	3.70 a
V_2	3.586 a	3.58 a
$T_{0.05}$	-2.023	0.767
Effect of insecticides		
T_1	4.78 a	5.84 a
T_2	3.01 c	3.16 c
T_3	1.72 d	1.31 d
T_4	4.20 b	4.27 b
$LSD_{0.05}$	0.37	0.36
Interaction effect of variety and insecticides		
V_1T_1	4.49 b	5.66 a
V_2T_1	5.07 a	6.01 a
V_1T_2	2.96 c	3.70 c
V_2T_2	3.05 c	2.62 d
V_1T_3	1.25 e	1.31 e
V_2T_3	2.19 d	1.30 e
V_1T_4	4.36 b	4.17 bc
V_2T_4	4.03 b	4.38 b
$LSD_{0.05}$	0.527	0.505
CV (%)	10.25	9.41

V_1= BARI Bt brinjal-2 (Bt Kajla), V_2= BARI brinjal-4 (Kajla), T_1= Untreated (control), T_2= Imidacloprid, T_3= Spinosad, T_4= Malathion.

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

4.3.5. Efficacy of treatments on infestation of brinjal shoot and fruit borer

The present study revealed a miraculous result in varietal treatments in case of BSFB (Table 8). V_1 showed no infestation of BSFB at vegetative stage and 4.905 number of BSFB infestation at fruiting stage.

In case of insecticidal treatments, T_3 showed the highest performance because it showed lowest number of BFSB infestation which was 0.93 percent and 2.71 percent at vegetative and fruiting stage respectively. On the other hand, the highest infestation of BSFB in T_1 which was 4.02 and 9.39 percent at vegetative and fruiting stage respectively. T_1 (9.39%) and T_4 (8.14%) showed statistically identical results. Combined interaction effect of varieties and treatments revealed significant results under the present study (Table 8). V_1T_3 showed no BSFB infestation at vegetative stage which was statistically similar to V_1T_1, V_1T_2 and V_1T_4 at the same growth stage (vegetative stage). V_1T_3 showed lowest number of BSFB infestation (0.79%) at fruiting stage. On the other hand, the highest number of BSFB was recorded in V_2T_1 which was 8.04% and 13.88% at vegetative and fruiting stage respectively. Spinosad has been proved to be the best insecticide in controlling BSFB according to the study of Shahana and Tayde (2017), Yousafi *et al.* (2015) and Patra *et al.* (2009). However, hackneyed use of malathion might reduce its effectiveness against BSFB.

Table 8: Effect of variety, insecticides and their interactions on the infestation of BSFB in brinjal field during Rabi season (from September 2017 to April 2018)

Treatments	Percent infestation (Vegetative stage)	Percent infestation (Fruiting stage)
Effect of Variety		
V_1	0.00 b	2.92 b
V_2	5.19 a	9.51 a
$T_{0.05}$	8.120	7.056
Effect of insecticides		
T_1	4.02 a	9.39 a
T_2	1.98 c	4.59 b
T_3	0.93 d	2.71 c
T_4	3.45 b	8.14 a
$LSD_{0.05}$	0.41	1.34
Interaction effect of variety and insecticides		
V_1T_1	0.00 e	4.905 bc
V_2T_1	8.04 a	13.88 a
V_1T_2	0.00 e	3.018 cd
V_2T_2	3.95 c	6.015 b
V_1T_3	0.00 e	0.790 e
V_2T_3	1.86 d	4.63 bcd
V_1T_4	0.00 e	2.795 d
V_2T_4	6.89 b	13.49 a
$LSD_{0.05}$	0.57	1.91
CV (%)	12.25	15.08

V_1= BARI Bt brinjal 2 (Bt Kajla), V_2= BARI brinjal 4 (Kajla), T_1= Untreated (control), T_2= Imidacloprid, T_3= Spinosad, T_4= Malathion.

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

4.3.6. Effect of treatments on the yield of brinjal

Yield is the most important characteristic as well as the ultimate expected outcome of a variety. Yield varies from variety to variety. In the present study, Bt brinjal (V_1) has given higher yield (36.317 ton/ha) where non-Bt brinjal (V_2) has given lower yield (35.422 ton/ha). Different insecticidal treatments showed different degrees of insect pest suppression i.e. interferes with the yield of crops. T_3 has showed the highest yield (36.974 ton/ha) where T_1 has showed the lowest yield (34.916 ton/ha). Combined treatments of varieties and insecticides showed no significant differences with the yield. But numerically, the highest yield was recorded in V_1T_3 that was 37.372 ton/ha which is statistically identical to V_1T_2 (36.608 ton/ha) and V_2T_3 (36.57 ton/ha). On the other hand, the lowest yield was recorded in V_2T_1 that was (34.427ton/ha) which was statistically similar to V_1T_1 (35.405 ton/ha) and V_2T_4 (35.0 ton/ha).

Higher yield of Bt brinjal has been ensured and reported by other researchers. Rashid et al. (2018) reported 13% higher yield of Bt brinjal than that of its corresponding non-Bt brinjal. Efficacy of Spinosad in controlling BSFB infestation has been proved by many studies and this can be attributed to the higher yield of brinjal. But the less infestation of BSFB in the rabi season may be the reason why non-Bt brinjal showed around similar production.

Table 9. Effect of variety, insecticides and their interactions on yield of brinjal

Treatments	Yield (t/ha)
Effect of Variety	
V_1	36.317 a
V_2	35.422 b
$T_{0.05}$	3.20
Effect of insecticides	
T_1	34.916 c
T_2	36.148 b
T_3	36.974 a
T_4	35.441 c
$LSD_{0.05}$	
Interaction effect of variety and insecticides	
V_1T_1	35.405 cd
V_2T_1	34.427 d
V_1T_2	36.608 ab
V_2T_2	35.688 bc
V_1T_3	37.372 a
V_2T_3	36.575 ab
V_1T_4	35.883 bc
V_2T_4	35.0 cd
$LSD_{0.05}$	NS
CV (%)	1.21

V_1= BARI Bt brinjal-2 (Bt Kajla), V_2= BARI brinjal-4 (Kajla), T_1= Untreated (control), T_2= Imidacloprid, T_3= Spinosad, T_4= Malathion.

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

Plate 2. Moth of brinjal shoot and fruit borer

Plate 3. Caterpillar of brinjal shoot and fruit borer

Plate 4. Shoot infestation by BSFB

Plate 5. Grub of epilachna beetle

Plate 6. Adult epilachna beetle

Plate 7. Harvested brinjal from experimental plot

CHAPTER V

SUMMARY, CONCLUSION AND RECOMMENDATION

Present study was designed to compare the incidence of major insect pests in Bt and non-Bt brinjal with reference to effectiveness of some promising insecticides in controlling these pests. Study reveals that eight insect pests and three natural enemies were found during the experiment. The insect pests were from five different orders namely lepidoptera, coleoptera, homoptera, neuroptera and acarina. Among them brinjal shoot and fruit borer, jassid, aphid, whitefly and epilachna beetle were found abundant and damage worthy.

So, the incidence study was done among these five major insect pests of brinjal. Findings showed that highest number of jassids were found from Bt brinjal (13.42 jassids/ five leaves) during 8^{th} SW whereas, highest number of jassids (12.32 jassids/ five leaves) found in non-Bt brinjal during 9^{th} SW. Highest number of aphids were found from Bt brinjal (10.35 aphids/ five leaves) in 1^{st} SW and 10.33 aphids/ five leaves in non-Bt brinal during 3^{rd} SW. Whitefly in Bt brinjal reached its final peak (10.32 whiteflies/ five leaves) during fruiting stage at 8^{th} SW while non-Bt brinjal experienced 10.33 whiteflies/ five leaves at its fruiting stage during the 9^{th} SW as the highest population. Damage percentage of epilachna beetle in Bt brinjal reached at its highest peak (8.65 percent damage/ five leaves) during 5^{th} SW, similarly in case of non-Bt, the highest (10.5 percent damage/ five leaves) peak was during the same week.

There was no shoot infestation reported in Bt brinjal but in non-Bt brinjal, highest shoot infestation (15.69%) was found during 9^{th} SW. Bt brinjal experienced highest infestation (11.5%) during 13th SW where the highest fruit infestation (17.63%) was found in non-Bt brinjal from 12th SW. Bt brinjal Sucking showed more susceptibility to sucking pests and chewing pests had better intrusion in non-

Bt brinjal. Reduced attack by chewing pests in Bt might increase the chance of higher infestation by sucking pests.

The results showed that the jassid infestation was lowest for treatment T_2 (6.41 and 10.8 in number at vegetative and fruiting stage respectively) and it was highest for T_1 (8.26 and 13.22 in number at vegetative and fruiting stage respectively). Best combination was found from V_2T_2 (6.33 and 8.39) that was statistically similar to V_1T_2 (6.50 and 13.49) in vegetative and fruiting stage respectively. Similarly, the lowest number of aphids was 8.22 and 8.83 at vegetative and fruiting stage respectively in treatment T_2 and best combination found from V_2T_2 (8.14 and 8.40 vegetative and fruiting stage respectively). In case of whitefly, the lowest number was reported from T_2 (6.52 and 8.45 at vegetative and fruiting stage respectively) and best combination found from V_2T_2 (6.16 and 8.31 at vegetative and fruiting stage respectively). The most effective insecticide found to control epilachna beetle (1.72 and 1.31 at vegetative and reproductive stage respectively) is T_3. The lowest number of epilachna beetle was recorded in V_1T_3 (1.25 and 1.31 at vegetative and fruiting stage respectively). V_1T_3 (1.31) and V_2T_3 (1.30) showed statistically similar result in case of fruiting stage. T_3 also played the most effective role in controlling BSFB infestation. Lowest shoot infestation (0.93 and 2.71 at vegetative and reproductive stage respectively) obtained from T_3. Best combination found from V_1T_3 as no shoot infestation and only 0.79 percent fruit infestation reported in this host-treatment interaction. In case of yield (t/ha) Bt brinjal (36.317 t/ha) gave higher yield that that of its corresponding non-Bt brinjal (35.722 t/ha). Spinosad (36.974 t/ha) performed better than any other insecticides. In each of the cases malathion performed worse in comparison to other insecticidal treatment (except control). Overuse of malathion in farming practice might make malathion less effective.

However, from this experiment followings are some important recommendations-

1. experiment on succession and incidence should be repeated for confirmation the activity of the major pests in other regions of Bangladesh to reach any concrete conclusion.
2. Further trials with described insecticides should be carried out in consecutive years.
3. Biotype studies on BSFB should be carried out.
4. Experiment on the abundance and diversity of natural enemies of brinjal pests in Bt brinjal field should be conducted.

CHAPTER VI
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APPENDICES

Appendix I. Factorial ANOVA Table for data on jassid in Bt and non-Bt brinjal for data on vegetative stage

Source	DF	SS	MS	F	P
Replication	3	0.2434	0.08114		
Insecticide	3	15.0665	5.02215	202.14	0.0000
Variety	1	0.4449	0.44486	17.91	0.0004
Insect*Var	3	0.0148	0.00493	0.20	0.3602
Error	21	0.5217	0.02484		
Total	31	16.2913			
Grand Mean	7.4529				
CV	4.11				

Appendix II. Factorial ANOVA Table for data on jassid in Bt and non-Bt brinjal for data on fruiting stage

Source	DF	SS	MS	F	P
Replication	3	0.0225	0.00750		
Insecticide	3	25.5424	8.51414	259.59	0.0000
Variety	1	5.8910	5.89103	179.61	0.0000
Insect*Var	3	0.3572	0.11908	3.63	0.0297
Error	21	0.6888	0.03280		
Total	31	32.5019			
Grand Mean	12.078				
CV	3.50				

Appendix III. Factorial ANOVA Table for data on aphid in Bt and non-Bt brinjal for data on vegetative stage

Source	DF	SS	MS	F	P
Replication	3	0.0405	0.01350		
Insecticide	3	24.0955	8.03182	264.13	0.0000
Variety	1	0.7442	0.74420	24.47	0.0001
Insect*Var	3	0.8606	0.28688	9.43	0.0004
Error	21	0.6386	0.03041		
Total	31	26.3794			
Grand Mean	9.4394				
CV	4.33				

Appendix IV. Factorial ANOVA Table for data on aphid in Bt and non-Bt brinjal for data on fruiting stage

Source	DF	SS	MS	F	P
Replication	3	0.0567	0.0189		
Insecticide	3	31.2298	10.4099	279.48	0.0000
Variety	1	0.0512	0.0512	1.37	0.0254
Insect*Var	3	4.1367	1.3789	37.02	0.0000
Error	21	0.7822	0.0372		
Total	31	36.2566			
Grand Mean	9.9300				
CV	6.25				

Appendix V. Factorial ANOVA Table for data on whitefly in Bt and non-Bt brinjal for data on vegetative stage

Source	DF	SS	MS	F	P
Replication	3	0.0471	0.01570		
treat	3	13.4121	4.47070	203.64	0.0000
var	1	2.8203	2.82031	128.46	0.0000
treat*var	3	0.3493	0.11644	5.30	0.0070
Error	21	0.4610	0.02195		
Total	31	17.0899			
Grand Mean	7.3181				
CV	6.62				

Appendix VI. Factorial ANOVA Table for data on whitefly in Bt and non-Bt brinjal for data on fruiting stage

Source	DF	SS	MS	F	P
Replication	3	0.0903	0.03010		
treat	3	15.0734	5.02448	214.63	0.0000
var	1	0.3763	0.37628	16.07	0.0006
treat*var	3	0.0059	0.00196	0.08	0.9681
Error	21	0.4916	0.02341		
Total	31	16.0375			
Grand Mean	9.4234				
CV	5.20				

Appendix VII. Factorial ANOVA Table for data on Epilachna in Bt and non-Bt brinjal for data on vegetative stage

Source	DF	SS	MS	F	P
Replication	3	0.2842	0.0947		
treat	3	44.1322	14.7107	119.22	0.0000
var	1	0.8192	0.8192	6.64	0.0176
treat*var	3	1.8718	0.6239	5.06	0.0086
Error	21	2.5913	0.1234		
Total	31	49.6986			
Grand Mean	3.4256				
CV	10.25				

Appendix VIII. Factorial ANOVA Table for data on epilachna in Bt and non-Bt brinjal for data on fruiting stage

Source	DF	SS	MS	F	P
Replication	3	0.4681	0.1560		
treat	3	87.1722	29.0574	247.26	0.0000
var	1	0.1339	0.1339	1.14	0.2979
treat*var	3	2.5417	0.8472	7.21	0.0017
Error	21	2.4679	0.1175		
Total	31	92.7838			
Grand Mean	3.6428				
CV	9.41				

Appendix IX. Factorial ANOVA Table for data on shoot infestation by BSFB in Bt and non-Bt brinjal

Source	DF	SS	MS	F	P
Replication	3	0.144	0.048		
treat	3	47.265	15.755	103.12	0.0000
var	1	215.126	215.126	1407.97	0.0000
treat*var	3	47.265	15.755	103.12	0.0000
Error	21	3.209	0.153		
Total	31	313.009			
Grand Mean	2.5928				
CV	12.25				

Appendix X. Factorial ANOVA Table for data on fruit infestation by BSFB in Bt and non-Bt brinjal

Source	DF	SS	MS	F	P
Replicati	3	2.348	0.783		
treat	3	229.831	76.610	45.58	0.0000
var	1	347.161	347.161	206.57	0.0000
treat*var	3	88.451	29.484	17.54	0.0000
Error	21	35.293	1.681		
Total	31	703.085			
Grand Mean	6.2112				
CV	15.08				

Appendix XI. Factorial ANOVA Table for data on yield (t/ha)

Source	DF	SS	MS	F	P
Replication	3	1.7520	0.58399		
treat	3	19.1099	6.36996	34.05	0.0000
var	1	6.3993	6.39925	34.21	0.0000
treat*var	3	0.0342	0.01139	0.06	0.9798
Error	21	3.9286	0.18708		
Total	31	31.2239			
Grand Mean	35.870				
CV	1.21				