EVALUATION OF PLANT EXTRACTS FOR THE MANAGEMENT OF BRINJAL SHOOT AND FRUIT BORER

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EVALUATION OF PLANT EXTRACTS FOR THE MANAGEMENT OF BRINJAL SHOOT AND FRUIT BORER

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CERTIFICATE

This is to certify that the thesis entitled "EVALUATION OF PLANT EXTRACTS FOR THE MANAGEMENT OF BRINJAL SHOOT AND FRUIT BORER" 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 (M.S.) **in** ENTOMOLOGY**, embodies the results of a piece of *bonafide* research work carried out by MD. ASHADUL ISLAM, Registration. No. 06-02062, under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma.**

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

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Dated:

Dhaka, Bangladesh

(Prof. Dr. Md. Abdul Latif)
Supervisor

ABBREVIATIONS

AEZ	:	Agro-Ecological Zone
Agric.	:	Agriculture
Agril.	:	Agricultural
ANOVA	:	Analysis of variance
BARC	:	Bangladesh Agricultural Researcher Council
BARI	:	Bangladesh Agricultural Research Institute
BAU	:	Bangladesh Agricultural University
BBS	:	Bangladesh Bureau of Statistics
CRD	:	Completely randomized design
DAS	:	Days after sowing
EFSB	:	eggplant fruit and shoot borer
FAO	:	Food and Agriculture Organization
IPM	:	integrated pest management
LSD	:	Least significant difference
RCBD	:	Randomized Complete Block Design
Viz.	:	Namely

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ABSTRACT

An experiment was conducted at the research field of Sher-e-Bangla Agricultural University (SAU), Dhaka-1207 during the period from November 2011 to June 2012 to evaluate the performance of some plant extracts for the management of brinjal shoot and fruit borer, (*Leucinodes orbonalis* Guenee). Experiment comprised 8 treatments including a control *viz.*, T_1: Tamarind fruit extract @ 50 g L^{-1} water, T_2: Morning glory leaf extract @ 50 g L^{-1} water, T_3: Bullok's heart leaf extract @ 50 g L^{-1} water, T_4: Neem leaf extract @ 50 g L^{-1} water, T_5: Tobacco leaf extract @ 50 g L^{-1} water, T_6: Mahogony seed extract @ 50 g L^{-1} water, T_7: Aktara 25 WG @ 0.5 g L^{-1} and T_8: Control. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Neem leaf extract @ 50 g L^{-1} water (T_4) produced the highest number of total shoots (16.00 $plant^{-1}$), healthy shoots (15.67 $plant^{-1}$), total fruits (25.33 $plant^{-1}$), healthy fruits (23.00 $plant^{-1}$), total fruits weight (2.711 kg $plant^{-1}$), healthy fruit weight (2.645 kg $plant^{-1}$) and fruits yield (36.15 t ha^{-1}). Lower number of infested shoot and fruits (0.33 and 2.33 $plant^{-1}$, respectively) and percentage (2.223 and 9.303%, respectively) were also found in neem leaf extract @ 50 g L^{-1} water (T_4), and infested fruits weight as well as its percentage was also lower (0.250 kg $plant^{-1}$ and 9.303% respectively) in the same treatment. In contrast, per cent protection of shoot and fruit borer over control was higher (92.45 and 91.26%, respectively) and fruit yield increase over control was also higher (61.74%) in this treatment. Control treatment performed poorly in all parameters. These results concluded that the use of neem leaf extract @ 50 g L^{-1} water would be highly effective to reduce the shoot and fruit infestation as well as to get higher yield of brinjal.

CHAPTER I

INTRODUCTION

The brinjal (*Solanum melongena* L.) is a plant belongs to the family of Solanaceae. Eggplant is a species of nightshade commonly known in British English as aubergine and also known as brinjal, eggplant, melongene, garden egg, or guinea squash (Yiu, 2006). As a member of the genus Solanum, it is related to both the tomato and potato. In the genus "*Solanum*" there are three main species viz; *escullantum* (large round), *serpentium* (long slender) and *depressum* (dwarf brinjal) (Chaudhry, 1976). Brinjal is one of the widely used vegetable crops and is popular in many countries *viz.*, Central, South and South East Asia, some parts of Africa and Central America (Harish *et al*., 2011). It originated in India, as Subcontinent people are used to grow brinjal since last 4000 years (Dunlop, 2006). Currently, it is extensively grown in Bangladesh, India, Pakistan, Nepal, U.A.E, Sri Lanka, Egypt and other warm countries of the world.

In Bangladesh, brinjal is the second most important vegetable crop next to potato in respect of acreage and production (BBS, 2012). The total area of eggplant cultivation is 31565.48 ha where 13759.31 ha in *Rabi* season and 17806.17 ha in *Kharif* season with total annual production of 246000 tons and the average yield is 15.81 t ha^{-1} in 2010-11 (BBS, 2012). Although the crop is grown throughout the country, it is intensively and commercially grown in Jessore, Rajshahi, Narsinghdi, Dhaka, Comilla and Bogra districts (Azad *et al*., 2012).

The yield potential of eggplant in Bangladesh is very low compared to other countries due to the incidence of insect pests and diseases which greatly hampered the production of eggplant (Das *et al*., 2000; Khan *et al*., 1998 and Rashid, 2000). Among the insect pests infesting brinjal, the major one is shoot and fruit borer, *Leucinodes orbonalis* (Guen.). By habit, it is an internal borer which damages the tender shoots and fruits. Its larvae feed inside brinjal fruit, making the fruit unmarketable and unfit for human consumption.

The yield loss due to the pest is 70-92% (Eswara Reddy and Srinivas, 2004; Chakraborti and Sarkar, 2011; Jagginavar *et al.,* 2009) and 85–90% (Misra, 2008; Jagginavar *et al*. 2009). The insect is becoming tolerant to the chemicals and making it more difficult to control. Besides, chemical pesticides are very expensive and threatens the health of farmers and consumers. The chemical also makes the vegetables poisonous, ecologically unsafe and economically unviable. Jayaraj and Manisegaran (2010) also reported that a single larva is enough to damage 4-6 healthy fruits. Mainly the brinjal is also damaged by this pest to a level of 31-86% fruit damage in Bangladesh (Alam *et al., 2003*) which may reach up to 90% under severe infestation.

Insecticidal control is one of the common means against the fruit borer (Harish *et al.,* 2011). However, a large quantity of information is available on the management of *L. orbonalis* including management by chemical methods (Tonishi *et al*., 2005; Hall 2007; Misra 2008; Lopez *et al*., 2010). But the new generation pesticide molecules have been claimed to be effective as well as safer for non-target organisms (Tonishi *et al*., 2005; Hall, 2007; Sontakke *et al*., 2007; Misra, 2008). As a result, different type of plant preparations such as powders, solvent extracts, essential oil and whole plants are being investigated for their insecticidal activity including their action as fumigants, repellents, antifeedants, anti-oviposition and insect growth regulators (Isman, 2000; Weaver and Subramanyam, 2000; Koul, 2004). Considerable efforts have been focused on plant derived materials, potentially useful as commercial insecticides (Essien, 2004; Koona and Dorn, 2005). Therefore, in the present study**,** an effort was made to manage the brinjal shoot and fruit borer (BSFB) by the use of some plant extracts and to reduce the cost of production. Keeping the above point in view, present investigation was planned to evaluate on “use of some plant extract for the management of BSFB” with the following objectives:

i. to determine the effect of different plant extracts on brinjal shoot and fruit borer and
ii. to find out the most effective plant extract for the management of brinjal shoot and fruit borer to ensure higher yield of brinjal.

CHAPTER II

REVIEW OF LITERATURE

Brinjal shoot and fruit borer *(Leucinodes orbonalis* Guenee) is a serious pest of brinjal and is responsible for colossal yield losses up to 70%. The pest is mainly controlled by chemical insecticides which pose serious threats to human and environment thus demands the use of alternatives. The present studies were conducted with the objective to use of plant extract to management of brinjal shoot and fruit borer. Many researchers have reported about plant extracts having antifungal and insecticidal properties and thus having potential to be used against many plant diseases and insects. It would help avoid environmental pollution caused by chemicals and thus become the most rewarding one in our existing socio-economic conditions and environmental threat. An attempt has, therefore, been made to review briefly the literatures on the use of tamarind (*Tamarindus indica* L.) fruit extract; bon kolmi (*Ipomoea carnea* Jace.), ata (*Annona reticulate* L.), neem (*Azadirachta indica* A. juss.) and tobacco (*Nicotiana tabacum* L.) leaf extract; mahogany (*Swietenia mahagoni* L.) seed extract and aktara for controlling plant diseases and insects of vegetables.

2.1 Origin and distribution of brinjal shoot and fruit borer

Hampson (1986) first described *L. orbonalis*. According to Butani and Jotwani (1984), *L. orbonalis*, the most serious pest of brinjal is not only distributed in the Indian sub-continent but also in South Afiica, Congo and Malaysia. Brinjal plants are severely attacked by brinjal shoot and fruit borer (BSFB) in the tropics but not in the Temperate Zone (Yamaguchi, 1983).

2.2 Biology of shoot and fruit borer

Egg: Adult females lay eggs on the foliage (Plate 1). The average number of eggs laid by a female varies from 80 to 253. 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. The eggs are flattened, elliptical and 0.5 mm in diameter. They are creamy-white soon after they are laid, but change to red before hatching. The egg incubation period is three to five days (Srinivasan, 2009).

Larva: The larva is creamy white to pink in the early stages. The grown-up larva is pink with sparse hairs on the warts on the body and a dark brown or blackish head (Plate 2). The full-grown larva measures about 16-23 mm in length. The larva usually has five instars, sometimes six. The larval period is about two weeks in summer and three weeks in winter. Soon after hatching from eggs, young caterpillars search and bore into tender shoots near the growing point, into flower buds, or into the fruits. Caterpillars prefer fruits over other plant parts. Larvae go through at least five instars (Atwal, 1976) and there are reports of the existence of six larval instars. Larval period lasts 12 to 15 days in the summer and up to 22 days in the winter. Sandanayake and Edirisinghe (1992) studied the larval distribution on mature eggplant in Sri Lanka. They found first instars in flower buds and flowers, second instars in all susceptible plant parts, third and fourth instars in shoots and fruits, and fifth instars mostly in fruits. Larval feeding in fruit and shoot is responsible for the damage to eggplant crop (Srinivasan, 2009).

Eggs on leaf iii

Plate 1. Eggs of *Leucinodes orbonalis*

Larvae on leaf

Plate 2. Larvae of *Leucinodes orbonalis*

Pupa: Mature larvae come out of their feeding tunnels and pupate in tough silken cocoons among the fallen leaves and other plant debris on the soil surface near the base of eggplant plants. The color and texture of the cocoon matches the surroundings making it difficult to detect (Plate 3). The pupa measures about 13 mm. Some studies indicate the presence of cocoons at soil depths of 1 to 3 cm. The pupal period lasts for 6 to 17 days depending upon temperature (Srinivasan, 2009).

Adult: Moths come out of pupal cocoons at night. Young adults are generally found on the lower leaf surfaces following emergence. Females are slightly bigger than males. The abdomen of the female moth tends to be pointed and curl upwards, whereas the male moth possesses a blunt abdomen. The moth is white but has pale brown or black spots on the dorsum of thorax and abdomen (Srinivasan, 2009). Wings are white with a pinkish or bluish tinge and are fringed with small hairs along the apical and anal margins (Plate 4). The adult life span is about a week; the females live longer than males. The forewings are ornamented with a number of black, pale, and light brown spots. The moth measures 20 to 22 mm across the spread of wings. Longevity of adults was 1.5 to 2.4 days for males and 2.0 to 3.9 days for females. The preoviposition and oviposition periods were 1.2 to 2.1 and 1.4 to 2.9 days, respectively (Mehto *et al*., 1983).

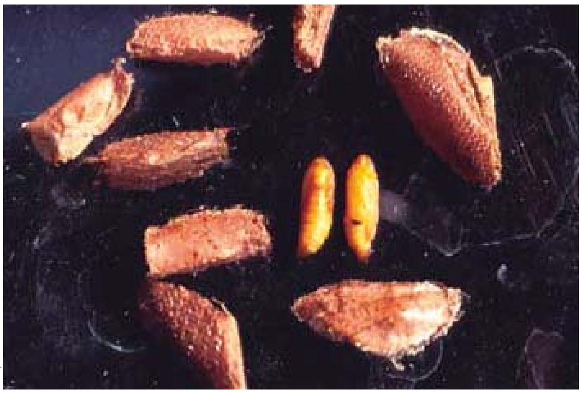


Plate 3. Pupa of *Leucinodes orbonalis*

Plate 4. Adult moth *Leucinodes orbonalis*

2.3 Host range of brinjal shoot and fruit borer

L. orbonalis is a serious pest of brinjal and it is also reported to infest potato and other solanaceous crops. Several wild species of *Solanum* are also attacked by this pest (Karim, 1994). The larvae also feed on pods of green peas (Alam *et al*., 1964). Isahaque and Chaudhuri (1983) observed that besides brinjal, some other plants served as host plant and the insect caused varying levels of infestation during different periods of the year. These plants were *Solanum nigrum, S. indicum, S. torvum, S. myriacanthum* and *S. tuberosum. S. myriacanthum* has been recorded as an alternative host-plant of the pest.

2.4 Damage symptoms of shoot and fruit borer

Brinjal shoot and fruit borer (BSFB) is mostly monophagous, sometimes also feeds on tomato, potato, *Solanum indicum* L., *S. xanthocarpum* Schrad. and Wendl., *S. torvum* Swartz., and *S. nigrum* L. (David, 2001; Alam *et al*., 2003). Upon hatching, the larva starts boring near the growing point or into the flower buds or fruits. During the early vegetative phase of the crop growth, it feeds on the tender shoots. Soon after boring into the shoots and fruits, the larva seals the entry hole with excreta. The larva tunnels inside the shoot and feeds on the inner contents. It also fills the feeding tunnels with excreta. This results in wilting of young shoots (Plate 5), followed by drying (Plate 6) and dropoff, which slows plant growth. In addition, it produces new shoots, delaying crop maturity. During the early reproductive phase, the larva occasionally feed on flower buds and flowers. However, it prefers to feed on the fruit rather than other plant parts during the fruiting stage of the crop. Damaged fruit exhibits boreholes on the surface, which often are sealed with excreta. The larva feeds inside the fruit creates tunnels filled with frass and fecal pellets (Plate 7). Hence, the fruit becomes unfit for marketing and consumption. Under heavy infestation, more than one larva will feed inside the same fruit.

Plate 5. Wilted shoot of eggplant damaged by *Leucinodes orbonalis*

Plate 6. Dried shoot of eggplant damaged by *Leucinodes orbonalis*

Plate 7. *Leucinodes orbonalis* feeding tunnels filled with excreta inside the damaged eggplant fruit

2.5 Nature of damage of shoot and fruit borer

In South and South-East Asia eggplant is extensively damaged by the infestation of a Lepidopteran insect, *L. orbonalis* commonly known as brinjal shoot and fruit borer (BSFB). During its cultivation, the total loss caused by the insect pest is 5-20% in shoot and 10-70% in fruit (Das and Singh, 2000).

Within one hour after hatching, (BSFB) larva bores into the nearest tender shoot, flower, or fruit. Soon after boring into shoots or fruits, they plug the entrance hole with excreta. In young plants, caterpillars are reported to bore inside petioles and midribs of large leaves. As a result, the affected leaves may drop off (Butani and Jotwani, 1984).

Larval feeding inside shoots result in wilting of the young shoot (Figure 8). Presence of wilted shoots in an eggplant field is the surest sign of damage by this pest. The damaged shoots ultimately wither and drop off. This reduces plant growth, which in turn, reduces fruit number and size. New shoots can arise but this delays crop maturity and the newly formed shoots are also subject to larval damage. Larval feeding in flowers—a relatively rare occurrence—results in failure to form fruit from damaged flowers.

Larval feeding inside the fruit results in destruction of fruit tissue (Figure 8). The feeding tunnels are often clogged with frass. This makes even slightly damaged fruit unfit for marketing. The yield loss varies from season to season and from location to location. Damage to the fruits in India, particularly in autumn, is very severe and the whole crop can be destroyed (Atwal, 1976). (BSFB) is active throughout the year at places having moderate climate but its activity is adversely affected by severe cold. (BSFB) is practically monophagous, feeding principally on eggplant; however, other plants belonging to family Solanaceae are reported to be hosts of this pest. They include tomato (*Lycopersicon esculentum*), potato (*Solanum tuberosum*), selected nightshades (*S. nigrum* and *S. indicum*), and turkey berry (*S. torvum*)

Figure 8. Symptoms of EFSB infestation in shoot (left) and fruit (right)

2.6 Effect of plant extracts on brinjal shoot and fruit borer infestation and their management practices

Mathur *et al*. (2012) studied to evaluate the efficacy of plant products viz., neem oil (2%), iluppai oil (2%), pungarn oil (2%), combination of iluppai and pungam (1: 1) and microbial formulations viz., entomopathogenic fungi, *Beauveria bassiana* and *Verticillium lecanii* against the brinjal shoot and fruit borer (BSFB), *Leucinodes orbonalis* Guenee. The results revealed that newer plant products i.e., oils of iluppai and pungam were at par with standard check endosulfan and were found to be significantly superior than microbial formulations and also showed better efficiency than neem oil in the suppression of BSFB infestation with significant insecticidal property. The yield data also revealed that the maximum yield of marketable fruits was obtained using iluppai oil (202.75 q ha^{-1}); the percent gain over control was least with *V. lecanii* followed by *B. bassiana*, neem oil, combination of iluppai and pungam oil, pungam oil, iluppai oil (77.8%), and maximum with endosulfan (83.3%). The results thus suggest that newer plant products such as oils of iluppai and pungum are promising botanicals in the integrated pest management strategy against BSFB.

Various management techniques were tested individually and in different combinations for the management of *L. orbonalis* (Javed, 2012) The integration of *Trichogramma chilonis*, hoeing and clipping of infested plant parts reduced fruit infestation to the maximum level (5.61, 6.14 and 6.66%) and maximum increase in yield (q $acre^{-1}$) (42.58, 35.99 and 39.29) at research farm PMAS Arid Agriculture University Rawalpindi, vegetable research farm NARC, Islamabad and Usman Khattar Vegetable Farm Taxila, Rawalpindi, respectively against *L. orbonalis* fruit infestation. Conclusively, the resistant cultivar “Nirala” and integration of different non chemical techniques (*Trichogramma chilonis* + hoeing + clipping) were recommended for the management of *L. orbonalis* in brinjal fields.

The study of Kalawate and Dethe (2012), bioefficacy of spinosad (56.25, 72 and 90 g a.i. ha-1) and emamectin benzoate (5, 6.25 and 12.5 g a.i. ha^{-1}) was studied in comparison to cypermethrin (50 g a.i. ha^{-1}) and self-formulated neem seed extract (5 %). Field experiments were undertaken for two cropping seasons during *kharif* 2005 and summer 2006. From the study it was found that spinosad afforded moderate control of jassid, whitefly and aphid. However, it was found to be the most effective against BSFB. Although corresponding yield recorded in cypermethrin (check treatment) was higher (16.30 and 21.01 t ha^{-1}) it was not significantly different than that noticed in spinosad and emamectin benzoate.

Saimandir and Gopal (2012) studied to evaluate against BSFB for the management of the pest. The mean initial deposits of indoxacarb on fruits were 2.60 mg kg^{-1} to 3.64 mg kg^{-1} and 2.63 mg kg^{-1} to 3.68 mg kg^{-1} from 75 and 150 g ha^{-1} treatments from two-year field studies. The mean initial deposits of thiacloprid on fruits were 3.39 to 5.40 mg kg^{-1} and 3.40 to 5.39 mg kg^{-1} from 30 and 60 g ha^{-1} treatments from both years. Thiacloprid at the experimented doses (30 and 60 g ha^{-1}) was found not effective to manage BSFB and was not safe for human consumption after a waiting period of 3 days. For methyl parathion, the method involving Florisil gave highest average recovery (89%). The efficacy of methyl parathion against BSFB was good at lower dose, but due to its toxic residue profile there is a high health risk. Biolep at both doses were not effective against (BSFB), however PUSA Bt gave better control against (BSFB) at similar dose. NSKE was found effective against BSFB, however NimboBas found to be non-effective against (BSFB).

An experiment was conducted by Azad *et al*. (2012) to evaluate the effect of eight botanical extracts on pest control in brinjal field. Accordingly, water extracts of dried leaves of Khuksa (*Ficus hispida*), Chotra (*Lantana* sp.), Chirata (*Swietia chrata*), Neem (*Azadiracta indica*), Bael (*Aegle marmelos*), Holde-hurhuri (*Cleomp viscosa*) and Marigold (*Targetes erecta*) and seeds of Mahogany (*Swietenia mahagoni*) were prepared and sprayed in experimental brinjal field at Rajshahi University. Out of these botanicals, Khuksha leaves extract showed best performance against the pest attack compare to other extracts. Marigold leaf extract also showed good performance in the protection of brinjal plant from pest. The efficacy of Chotra, and Chirata leaf extracts was nearly same in brinjal plot against the pest attack. Neem leaf extracts showed moderate performance against pest. Mahogany seed extract showed lowest efficacy and hampered the normal plant growth and caused fruit rottening as well as reduced the yield of brinjal. Although Khuksha, Beal and Marigold leaf extracts were found effective against brinjal pests but a higher production was observed in the treatments of Neem and Chirata leaf extracts in experimental brinjal field.

Dutta *et al*. (2011) conducted an experiment for sustainable management of the pest of brinjal. Out of which the module with three different component, viz., Pheromone trap, mechanical control and application of peak neem (neem based insecticide) was found best in reduction of shoot damage (86.69%), fruit damage (59.36%) and yield increase (96.94%). This was followed by Pheromone trap + Peak neem in terms of shoot damage (79.24%), Farmers practices in terms fruit damage (54.13%) and Pheromone trap + Peak neem in terms of yield increase (68.64%). While simultaneous application of trap and peak neem afforded 79.24% and 47.70 per cent protection against shoot and fruit damge respectively.

An effort was made by Chakraborti and Sarkar (2011) to control the borer during the Indian rainy season, as this is the time when the problem is at its worst. Integration of phytosanitation, mechanical control and prophylactic application of neem seed kernel extract (NSKE) exerted a satisfactory impact on the incidence and damage of *L. orbonalis*. After two need-based applications of new generation pesticide molecules like flubendiamide or rynaxypyr or emamectin benzoate, fairly good, healthy yields were produced.

These results are in consistent with Anil and Sharma (2010) wherein, they found that spinosad and emamectin benzoate were effective in suppressing the fruit infestation by BSFB.

Rajendra (2010) reported that brinjal shoot and fruit borer damage was comparable to the chemical insecticide treatment and the higher dosage of Neemazal (5 ml L^{-1}) across observations. Analysis of average data indicated that SoluNeem at 1.0 g L^{-1} were superior resulting in lowest shoot borer incidence compared to all other treatments, except SoluNeem at 0.5 g L^{-1}. SoluNeem at 0.5 g L^{-1} was as effective as the chemical insecticides and better than Neemazal formulation of Neem. The average fruit borer incidence was significantly reduced in SoluNeem treatments at 1.0 g L^{-1} (17.83%) followed by 0.5 g L^{-1} (22.87%) compared to the chemical insecticide treatment (31.67%) and other botanical treatments (35-47%) and untreated control (66%). The marketable yield (after removal of damaged fruits from the lot) from different treatment ranged from 11.44 q $acre^{-1}$ (untreated control) to 37.65 q $acre^{-1}$ (SoluNeem @ 1.0 g L^{-1}). It was significantly higher in SoluNeem at 1.0 g L^{-1} compared to all other treatments. SoluNeem at 0.5 g L^{-1} and the chemical insecticide treated plots produced equally (35.50 and 34.31 q $acre^{-1}$, respectively). Neemazal at 5 ml L^{-1} produced 28.52 quintal fruits per acre, significantly lesser than SoluNeem treatments at 1.0 and 0.5 g L^{-1}, but the yield difference was non-significant between SoluNeem at 0.5 g L^{-1} and Neemazal 5 ml L^{-1} treatments.

Chatterjee (2009) studied to formulate a realistic sustainable management module for brinjal shoot and fruit borer (*Leucinodes orbonalis*) a field experiment was carried out during March to September 2006 at four villages near Sriniketan. The module with three components i.e. pheromone trap, timely mechanical control and application of azadex (neem based insecticides) was found most effective in reduction of shoot damage (76.59%) followed by the farmer's practice (*i.e.* twenty times application of insecticides) (76.36%). Whereas highest protection in fruit damage (48.26%) and yield increment (53.19%) were obtained from the practices of setting trap + timely mechanical control and trap + application of azadex, respectively. The module having all three components was found next best, which provided 45.91 per cent less fruit damage coupled with 52.29 per cent more production. Moreover, setting of only pheromone trap @ 75 numbers per hectare gave quite substantial protection in shoot damage (58.35%), fruit damage (33.73%) and yield

(28.67%) while simultaneous use of trap + azadex afforded 71.72 and 39.06 per cent protection against shoot and fruit damage, respectively. Comparative study of different lures proved that NRI lure was significantly superior over PCI lure in respect of male moths trapped in every week as well as in total catch, but insignificant differences were found with Agriland and Ganesh lures. Efficacy of these two lure remained at par throughout the installation period but differed significantly from PCI lure in 2nd, 3rd week and in 2nd week, total catch respectively.

A field trial was conducted by Ghatak *et al*. (2009) to assess the bio-efficacy of two indigenous plant products viz., seed extracts of *Annona squamosa* (Annonaceae) and *Strychnos nuxvomica* (Loganeaceae) using methanol as solvent and an entomopathogenic fungus, *Verticillium lecanii*, in controlling brinjal shoot and fruit borer, *Leucinodes orbonalis* Guen. of brinjal. Both the botanicals were used at 2.0 ml, 3.0 ml and 4.0 ml lit^{-1} of water, while for *V. lecanii*, these were 1.5 g, 2.0 g and 3.0 g lit^{-1} of water. Besides untreated control, emamectin benzoate 5% SG was used at 0.22 g, 0.28 g and 0.56 g lit^{-1} of water, for comparison. The results indicated a reduction in fruit damage in the range of 71.98% to 76.94%, 65.99% to 66.79% and 58.67% to 66.79% respectively, over control, in treatments with *A. squamosa, S. nuxvomica* and *V. lecanii*, while in case of emamectin benzoate, it was 69.93% to 73.04%.

The integrated pest management (IPM) strategy for the control of brinjal shoot and fruit borer (BSFB) consists of resistant cultivars, sex pheromone, cultural, mechanical and biological control methods (Srinivasan, 2008). Use of BSFB sex pheromone traps based on (E)-11-hexadecenyl acetate and (E)-11-hexadecen-1-ol to continuously trap the adult males significantly reduced the pest damage on eggplant in South Asia. In addition, prompt destruction of pest damaged eggplant shoots and fruits at regular intervals, and withholding of pesticide use to allow proliferation of local natural enemies especially the parasitoid, *Trathala flavo-orbitalis* reduced the BSFB population. The IPM strategy was implemented in farmers' fields via pilot project demonstrations in selected areas of Bangladesh and India and its use was promoted in both countries.

Singh *et al*. (2008) studied to assess the field efficacy, economic viability and reasons for non adoption of alternative IPM tools *vis a vis* pesticides against brinjal shoot and fruit borer (*Leucinodes orbonalis* Guen.). Neem (Azadirachtin) based products such as Multineem, neem seed kernel extract (NSKE), neem oil and neem cake were found ineffective against BSFB. Mass trapping + neem oil spray + shoot clipping gave significantly higher protection resulting in 38.0 per cent improvement over untreated plots, but damage was still high as against pesticide treated plots. The most effective treatment was cypermethrin @ 30 g ha^{-1} against the pest, which was superior to any of the IPM tools or their combinations tested in present experiments. Chemical control recorded highest protected yield (132.5 q ha^{-1}). Mass trapping supplemented with neem spray and clipping was second in order to fetch higher protected yield (55.2 q ha^{-1}) than other less effective treatments.

Incidence of *Leucinodes orbonalis* in terms of shoot infestation was observed by Babu *et al*. (2008) during third week of February 2006 and the incidence had non-significant relationship with temperature, relative humidity and rainfall but significant relationship with coccinellids and spiders. The results of chemical control trial indicated that profenofos 0.1% and spinosad 0.015% were most effective in reduction of shoot infestation of *L. orbonalis* besides recording higher brinjal fruit yield. Among the 15 treatments tested, profenofs was the most effective followed by spinosad individually and their combination with novaluron and azadirachtin were highly effective in reducing the population as well as in giving higher yields.

In two year study was conducted by Varma *et al*. (2009), maximum population of brinjal shoot and fruit borer, *Leucinodes orbonalis* in Allahabad, U.P. was observed in 5th and 2nd week of December during 1st and 2nd year respectively. The brinjal shoot and fruit borer incidence showed positive correlation with maximum relative humidity, rainfall and wind speed during 1st year and with maximum relative humidity and sunshine hours in 2nd year. The damaged fruit and fruit weight loss varied from 3.76 to 45.45 percent and 3.00 to 67.71 percent in 1st year and 5.71 to 44.26 percent and 3.00 to 51.33 percent in 2nd year.

One larval parasitoid of brinjal shoot and fruit borer, *Eriborus argentiopilosus* (Hymenoptera: Ichneumonidae) was identified. The extent of parasitization ranged from 2.01 to 24.61 percent. Most effective treatment was application of Chlorpyriphos followed by NSKE (5%) and Nerium (10%).

Gautam *et al*. (2008) reported that the insecticides endosulfan, malathion and quinalphos proved most effective in reducing shoot infestation by 90.00, 87.5 and 80.0%, respectively. Among botanicals, neemarin and achook were significantly on par and effective by 78.5 and 77.6% followed by bioneem 69.6% respectively in reducing shoot infestation over control. Bio-pesticides, however, register 60.8% and 59.6% reducing in shoot infestion in case of dipel and diolep, respectively. The maximum fresh fruit yield (21.778 t ha^{-1}) was obtained in endosulfan treated plot followed by malathion (19.222 t ha^{-1}) and quinalphos (17.722 t ha^{-1}) The fruit yield losses in case of endosulfan and malathion were (4.4%) and (5.5%) followed by quinalphos (6.9%). Neemarian and achook were significantly on par and registered 9.2 and 10.6% yield loss, respectively followed by bioneem 14.6%.

Field experiments were carried out by Adiroubane and Raghuraman (2008) with nine treatments were laid out in a Randomized Block Design (RBD) with three replications during February 2005 - August 2005 and February 2006 - May 2006. The borer infestation was recorded on shoot and fruits (number basis) on randomly selected five plants from each treatment per plot. *Pongamia pinnata* (L) (PPO) (2%), *Madhuca indica* (J.F.Gonel) oil (MIO) (2%), PPO +MIO in 1:1 (2%), oxymatrine 1.2 EC (0.2%) (M/S. Jasmine Biological Pvt. Ltd., Hyderabad), spinosad 45 SC (225 g.a.i. ha^{-1}), acephate 75 SP (750 g.a.i. ha^{-1}), carbaryl 50 WP + wettable sulphur 50 WP (1:1), neem seed kernel extract (NSKE 5%) along with untreated check were used as treatments. Oxymatrine (1.2 EC @ 0.2 per cent) and spinosad (45 SC @ 225 g a.i. ha^{-1}) were found to be effective against brinjal shoot and fruit borer, *Leucinodes orbonalis* (Guenee.). Oxymatrine was effective at early vegetative stage. Highest per cent reduction of shoot damage was observed in oxymatrine and it is on par with spinosad Spinosad was effective at fruiting stage. Maximum per cent reduction of fruit damage was recorded in spinosad and it was on par with oxymatrine.

Due to adoption of IPM technology for the controlling of brinjal fruit and soot borer (*Leucinodes orbonalis*), there were about 4.7, 34.0 and 53.8 % change in yield, fresh fruit and profit amongst brinjal growers (Mandal *et al*., 2008). The impacts of IPM practice have its positive effect on brinjal area increasing to 21.6% for adopters while decreasing to 8.7% for non-adopters. IPM practices could not stop pesticide use but able to reduce it substantially as IPM farmers had to apply 52.6% less quantity pf pesticide however, for non-adopters it increased by 14.1%. All the farmers adopting IPM technology agreed that high cost of pesticide, convenience of IPM practices, potential health hazards of pesticides and profitability of IPM technology were responded by 91, 75, and 71% farmers, respectively. The internal rate of return as well as benefit-cost ratio was also very high indicating thereby, large potential economic impact of the IPM technology to control EFSB in the study area.

Prasad and Devappa (2006), wherein emamectin benzoate at 10 g a.i. ha^{-1} was found to be effective in reducing the dead hearts and fruit damage in brinjal. Nevertheless, the dose of emamectin benzoate used by these workers was higher than 6.25 g a.i. ha^{-1} which showed better control in this study. Emamectin benzoate treatments provided yield to the tune of 14.46 to 15.14 and 19.22 to 19.95 t ha^{-1} in *kharif* and summer, respectively.

Khattak and Rashid (2006) reported that neem (*Azadirachta indica*) oil at 1.5 and 2.0% and neem seed water extracts at 2.0 and 3.0% significantly reduced the population of spotted bollworms (*Earias* spp.) and American bollworms (*Helicoverpa armigera*) up to 168 h after spray. Neem oil at 2.0% and neem seed water extracts at 3.0% remained effective up to 336 h after spray; as significantly lower number of bollworms larvae settled on bolls treated with 2.0% neem oil and 3.0% neem seed water extract. Similarly, neem oil at 2.0% and neem seed water extract at 3.0% significantly affected the egg parasitization of *Trichogramma* spp.

An experiment carried out with the use of bio fertilizers in addition to farm yard manure neem cake, poultry manure and macho cake, the infestation of shoot and fruit borer can be reduced. They showed that the shoot and fruit borer damage was consistently less in the plots treated with PM + Bio fertilizers + N.C. PM +Bio fertilizers + NC, along with the field release of bio control agents and FYM + Bio fertilizers + NC+ field release of bio control agents significantly reduced the shoot and fruit borer damage throughout duration of the experiment (Kavilharaghavan *et al.,* 2006).

Perumala and Vatsala (2005) studied the different vegetable crops such as carrot, okra and brinjal cultivated in soil amended with different manures such as organic amendments and biodynamic forms. The vegetable cultivated in experimental plots with organic and biodynamic manures recorded fewer pests and disease attack and produced comparable yield.

In a field experiment conducted to study four components of integrated Pest Management, including application of neem, oil cake at 100 kg acre^{-1} at transplanting stage in 45 days old crop on weekly basis, and Mechanically removal of infested shoots following neem oil spray at 10-12 days intervals. These IPM components significantly reduced *L. orbonalis* infestation on brinjal cultivars. This approach has demonstrated better yield of marketable fruits, with increase in cost (Rath and Maity, 2005).

Evaluation of an integrated pest management module for the management of brinjal shoot and fruit borer (*L. orbonalis*) was done in the fields. This IPM module includes, the application of neem cake at 100 kg acre^{-1} (50kg during land preparation, and 50 kg at three weeks after transplanting), mechanical clipping of infested shoot on weekly basis and spraying of neem oil every 10-12 days interval. A socio-economic survey among the user was also conducted. Comparison of IPM and Non IPM plot has demonstrated a clear difference in infested shoots which was 1.83 and 1.79% in IPM plots while 12.67 and 9.52% in Non IPM. Fruit damage in IPM plots was also lower which was 13.07 and 6.56% while in non IPM plots it was 43.34 and 27.30%. This experiment also gave higher average yields (12-20 and 13-10 t/ha.) and cost: benefit ratio (1:1.81 and 1:2.95) (Rath and Dash, 2005).

Cork *et al*. (2005) noted that the extracts from neem extract, Cinnamon *(Cinnamomum cassia)*, Anise (*Illicium verum)* and Fennel (*Foeniculum vulgare)* as well as cinnamon oil, horse radish oil and mustard oil acted rapidly against pest and caused over 80% mortality to brinjal shoot and fruit borer.

A field experiment was conducted by Satpathy *et al*. (2005) to study the feasibility of using *Trichogramma chilonis* for management of brinjal shoot and fruit borer. There were three treatments consisting of inundative release of *T. chilonis* alternated with endosulfan @ 350 g ai ha^{-1}, neem seed kernel extract (4%) and shoot clipping (weekly) along with the untreated control. Foliar spray of endosulfan and neem was applied 7 days after *Trichogramma* release, whereas *Trichogramma* was released 10 days after the foliar spray. The treatments were initiated 35 days after transplanting. Fruit damage was recorded at 10 days interval from 50 days after transplanting (DAT). Observations on fruit damage were made from four randomly selected spots comprising of 30 plants each. Initially, the relative level of fruit damage between treated and untreated plot was not prominent. However, in later harvests the treatment effect became more pronounced. During the peak infestation period at 90 DAT, the fruit infestation in control plot was 84.32 per cent compared to 58.00 and 60.00 per cent in T_1 and T_2, respectively. Fruits infestation was higher in control plots (84.32%), compared to *T. chilonis* + endosulfan (T_1) and *T. chilonis* + shoot clipping + NSKE (T_2) (58 and 60%, respectively). In all the pickings from 50 to 140 DAT, the average fruit damage in T_1, T_2 and control plot was 46.34, 45.15 and 59.47 per cent, respectively. The level of damage in both the treatments was significantly less than the control, whereas there was no significant difference in fruit damage between T_1 and T_2. The conjugation of *T. chilonis* release and either shoot clipping + NSKE (4%) spray or endosulfan foliar spray @ 350 g ai ha^{-1} reduced shoot infestation.

Venkatesh *et al.* (2004) studied the influence of application of five organic manures *viz.*, neem cake, pongamia cake, castor cake (all at 1.0 t ha^{-1}), farmyard manure and vermicompost (10.0 t ha^{-1}) alone and in combination with chemical fertilizer against *L. orbonalis*, whitefly and leaf hopper in brinjal.

Among the cakes, neem cake was the most effective. Significantly higher yield (40.3 q ha^{-1}) was obtained from neem cake treated plots followed by vermicompost and castor cake treated plots.

The comparison of efficacy of insecticide and neem products against shoot and fruit borer was conducted in a field experiment. It was observed that Triazophos 0.5 kg gave the lowest average fruit borer incidence (14.36%) and highest fruit yield (20.75%) (Mishra *et al*., 2004).

Nandagopal and Ghewande (2004) determined the efficacy of neem (*Azadirachta indica*) extracts against *Holotrichia consanguinea*, *Aproaerema modicella*, *Spodoptera litura*, *Helicoverpa armigera*, *Balclutha hortensis* [*Balclutha incisa*], *Empoasca kerri*, *Caliothrips indicus* and *Aphis craccivora* infesting groundnuts in India. The effects of neem on *Cercospora arachidicola* [*Mycosphaerella arachidis*], *Phaeoisariopsis personata* [*Mycosphaerella berkeleyi*], *Puccinia arachidis*, *Alternaria alternata*, *A. tenuissima*, *Aspergillus niger*, *A. pulverulentus*, *Sclerotium rolfsii* [*Corticium rolfsii*] and *Macrophomina phaseolina* infecting ground nuts are also discussed.

Five alternate sprays of insecticide; Thiodan, 35 EC at 2l ha^{-1}, Sevin, 50WP at 2 kg ha^{-1}, Monocil 36EC at 1375 ml ha^{-1}, Decis 2.8EC at 400 ml ha^{-1} were recommended in open field condition i.e., they were applied on appearance of pest, in comparison to net house condition where the soil was sterilized by Formalin and no insecticide spray was applied to control pest. Thus on weekly basis, clean cultivation was performed.The removal of infested shoots was done along with each fruits picking infested by *L. orbonalis* to destroy them mechanically. It was concluded that net house crops were better protected as lower fruit damage (2.8-2.9%) was recorded when compared with field condition even after spray; the damage was 55.08% (Sandeep *et al*., 2004).

The effectiveness of chemical and non-chemical insecticides was compared against major pests of brinjal. The Spark and monocrotophos were found to be most effective insecticides for the sucking insect complex. However, BT and

Spark were found highly effective against *L. orbonalis* and they received increased fruit yield (Mote and Shivu, 2003).

Singh (2003) reported the control of brinjal shoot and fruit borer with combination of plant products and insecticides. Among the different treatments tested, basal application of neem cake @ 20 q ha^{-1} + foliar spray of quinalphos 0.05% was effective in reducing the fruit borer incidence (20.63%) and increased the yield (82.59 q ha^{-1}) compared to control (27.7 q ha^{-1}). However, foliar spray of neem oil at 3 per cent + basal application of neem cake @ 20 q ha^{-1} was on par with it.

Jyothi and Sannaveerappanavar (2003) tested the activity of aqueous neem seed kernel extract (NSKE) and neem seed oil against the egg parasitoid, *Trichogramma chilonis* and *Corcyra cephalonica* under laboratory conditions. NSKE at 2 and 4% and neem seed oil at 4% were moderately toxic to *T. chilonis* adults, causing 33.33, 31.24 and 29.58% mortality, respectively.

Neem oil at 2 and 5% and NSKE at 4% significantly reduced the parasitization of *C. cephalonica* to 49.22, 57.41 and 59.29%, respectively, compared with 88.91% in the control.

Godse and Patel (2003) reported the effect of organic manures and fertilizers on the incidence of brinjal shoot and fruit borer *L. orbonalis.* The lowest incidence of fruit borer was observed in neem cake @ 1,700 kg ha^{-1} (6.08%). However, it was at par with vermicompost @ 4,000 kg ha^{-1}, double dose of K_2O and half dose of FYM + half dose of fertilizer.

Study on the identification, distribution and efficiency of entomopathogenic nematodes was carried out. The entomopathogenic nematodes were found effective against *L. orbonalis* (Hussaini *et al*., 2003a). Comparative study for the current status of research on the use of entomopathogenic nematodes as biological control agents including the target vegetable pests, their culturing and bioefficacy against *Earias vittella, Agrotis ipsilon, L. orbonalis* and *S. litura.* They also compared their compatibility with neem products, pesticides and oil cakes (Hussaini *et al.,* 2003b).

The isolation of *S. bicornutum, H. indica* and *S. carpocapsae* recorded maximum mortality of *L. orbonalis* at an inoculation rate of 50 infected juveniles (IJs)/larva (against 25 and 100 IJs/larva) within 48 to 72 hrs. of exposure. They compared their results with sprays of neem seed kernel extracts (Hussaini *et al*., 2002).

Study for evaluation of natural parasitoids and extent of parasitism to brinjal shoot and fruit borer was performed. They found three parasitoids namely *Trathala flavo-orbitalis*, an unidentified dipteran fly and an unidentified mermaid. Rate of parasitism was more in later crop stage with mild weather conditions compared to hot and dry climate (Singh and Singh, 2002).

Comparative study of different formulations of *Bacillus thuringiensis* (biological agent), neem and chemical insecticides against brinjal shoot and fruit borer was carried out. Five sprays of Dipel have demonstrated 10% reduction in fruit and shoot damage (Puranik *et al.*, 2002).

Studies on the management of brinjal shoot and fruit borer *L. orbonalis* by application of neem cake (250 kg ha^{-1}) four times during the crop growth period decreased the incidence of borer to 8% from 40 per cent (untreated) and the yield has increased to nearly 68% from 10.93 t ha^{-1} giving an additional income of Rs. 35,498 ha^{-1}. The cost of production of brinjal has come down to more than half (to Rs. 2.23 kg from Rs. 4.80 kg^{-1}). The use of neem cake to manage the brinjal shoot and fruit borer was not only found economically feasible in terms of productivity and profitability but also it is ecofriendly (Sreenivasa Murthy *et al.*, 2001).

Rosaih (2001a) reported that neem oil 0.5% was significantly superior in reducing the whitefly population and brinjal shoot and fruit borer damage. Rosaih (2001b) evaluated different botanicals against pest complex of brinjal. Neem seed kernel extract (NSKE) at 5 per cent recorded least shoot damage (15.61%) and fruit damage (35.60%) and this was followed by Neemazal 0.5 per cent with 16.1 per cent and 25.51 per cent shoot and fruit damage, respectively.

Krishnamoorthy *et al.* (2001) evaluated the effect of application of neem and pongamia cake @ 250 kg ha^{-1} while planting and twice or thrice at 30 days interval on various vegetables. In brinjal it reduced the shoot and fruit borer incidence to 6-10% compared to 30-50 per cent in insecticide treated plots.

When field experiment conducted to evaluate different insecticide's mixture and natural enemies against this pest (Naitam and Mali, 2001). The cartap was found to be the most effective against BSFB.

Evaluation of eco-friendly insecticides against *L. orbonalis* was done and Cypermethrin was found to be the most effective followed by Carbaryl and Endosulfan. Neem based insecticides were found least effective against this pest (Jat and Pareek, 2001).

An experiment was conducted for the management of brinjal shoot and fruit borer *L. orbonalis* using different plant extracts, pongamia oil 2 percent treated plot recorded less fruit damage (11.40%) and provided highest yield (39.66 q/ha). This was followed by leaf extract of *Vitex negundo* L. (Eswara Reddy and Srinivasa, 2001).

CHAPTER III

MATERIALS AND METHODOLOGY

An experiment was conducted at the research field of Sher-e-Bangla Agricultural University (SAU), Dhaka-1207, during the period from November 2011 to June 2012 to evaluate six plants extracts for the management of brinjal shoot and fruit borer (BSFB). This section for convenience of presentation has been divided into various sub–sections such experimental site, soil and climatic condition, experimental materials, land preparation, experimental design, fertilizer application, seed sowing, plant extract preparation and their application, intercultural operations, harvesting, data collection, statistical analysis etc.

3.1 Description of the experimental site

3.1.1 Experimental site

The experimental field is located at 90.335° E longitude and 23.774° N latitude at a height of 1 (one) meter above the seas level (Iftekhar and Islam, 2004).

3.1.2 Soil

The soil of the experimental field belongs to the Tejgaon soil series of the Madhupur tract under Agro ecological Zone (AEZ-28) (UNDP and FAO, 1988). The general soil Type of the experimental field is deep red brown terrace soil. Topsoil is silty clay loam in texture. Organic matter content was very low (1.34 %) and soil pH varies from 5.8-6. The land was above flood level and well drained. The initial morphological, physical and chemical characteristics of soil are presented in the Appendix I.

3.1.3 Climate

The experimental area is situated in the sub-tropical climatic zone and characterized by heavy rainfall during the months of April to September (Kharif Season) and scanty rainfall during the rest period of the year (Biswas, 1987). The Rabi season (October to March) is characterized by comparatively low temperature and plenty of sunshine from November to February (SRDI, 1991).

The average maximum temperature is 24.94°C and average minimum temperature is 19.19°C. The average mean temperature is 21.89°C. The experiment was done during the *rabi* season. Temperature during the cropping season ranged between 13.46 C to 30.93°C. The humidity varies from 73.57 to 87.55%. The day length was 10.5-11.0 hours only and there was no rainfall from the beginning but some rain was recorded in March to harvesting. The monthly average temperature, humidity, bright sunshine, solar radiation of the site during the experimental work is presented in Appendix II.

3.2 Experimental materials

3.2.1 Planting materials

Variety

Brinjal variety Singhnath was used as experimental materials for the study which was released from Bangladesh Agricultural Research Institute (BARI). The seed of the variety was collected from BARI, Joydebpur, Gazipur.

3.2.2 Treatments

The experiment had the following eight treatments of plant extract including control and their scientific name were also presented

T_1: Tamarind (*Tamarindus indica* L.) fruit extract @ 50 g L^{-1} water (T_1)

T_2: Morning glory (*Ipomoea carnea* Jace.) leaf extract @ 50 g L^{-1} water (T_2)

T_3: Bullock's heart (*Annona reticulate* L.) leaf extract @ 50 g L^{-1} water (T_3)

T_4: Neem (*Azadirachta indica* A. juss.) leaf extract @ 50 g L^{-1} water (T_4)

T_5: Tobacco (*Nicotiana tabacum* L.) leaf extract @ 50 g L^{-1} water (T_5)

T_6: Mahogony (*Swietenia mahagoni* L.) seed extract @ 50 g L^{-1} water

T_7: Aktara 25 WG @ 0.5 g L^{-1} water

T_8: Control

3.3 Experimental design and layout

The experiment consisted of eight treatments including six plant extracts and a control was laid out in Randomized Complete Block Design (RCBD) with three replications. The experimental field was divided into three equal blocks and each block was again divided in to 8 equal plots. Thus there were 24 (3 × 8) unit plots all together in the experiment. The size of each unit plot was 3.0 m × 3.0 m, row to row and plot to plot distances was 1.0 m and 1.0 m, respectively while plant to plant distance was 75 cm. The treatments of the experiment randomly distributed into the experimental plot. Details layout of the experimental plot were presented in Appendix III.

3.4 Raising of eggplant seedlings in plastic trays

Seedlings were raised in plastic trays in the net house of the Department of Plant Pathology, SAU with proper care and management to ensure disease free healthy growth of seedlings (Islam, 2006).

3.5 Sterilization of soil and preparation of plastic tray

Soil for raising seedlings in plastic tray was prepared by mixing soil with sand and well decomposed cow dung in the proportion of 2:1:1. Formalin solution (5%) was mixed with heaped soil uniformly@ 200 ml/cft. The soil heap was covered with black polythene sheet for 48 hours. The heap was uncovered and soil was spaded to remove the fume of formalin. After seven days of soil treatment, sterilized plastic trays (35 cm × 25 cm) were filled with sterilized soil.

3.6 Sowing seeds in plastic trays and care of seedlings

One hundred seeds were sown in each tray. Soil moisture was maintained through watering. Shade was provided to save the young and delicate seedlings from heavy showering and scorching sunlight (Islam, 2006).

3.7 Land preparation

Power tiller was used for the preparation of the experimental field. Then it was exposed to the sunshine for 7 days prior to the next ploughing. Thereafter, the land was ploughed and cross-ploughed to obtain good tilth. Deep ploughing was done to produce a good tilth, which was necessary to get better yield of this crop. Laddering was done in order to break the soil clods into small pieces followed by each ploughing. All the weeds and stubbles were removed from the experimental field. The plots were spaded one day before planting and the whole amount of fertilizers were incorporated thoroughly before planting according to fertilizer recommendation guide (Islam, 2006).

3.8 Fertilizer and manure application

After opening the land, well decomposed cowdung was applied and thoroughly mixed up with soil. Before final land preparation, inorganic fertilizers were applied. Fertilizer and manure dose were calculated on the basis of fertilizer Recommendation Guide of BARC (Anonymous, 2005).

Manures and Fertilizers Applied in the Field

Fertilizer	Rate (kg ha^{-1})
Cowdung	10000
Oilcake	500
Urea	140
TSP	120
MP	100

- All cowdung, oil cake, TSP and half dose of MP were applied during land preparation.
- Urea and remaining half dose of MP were applied in the installments as side dressing.

3.9 Transplanting of seedlings

Healthy seedlings grown with intensive care in plastic tray were transplanted in the field at the age of 45 days in the field in the afternoon followed by watering. Fifteen healthy seedlings were transplanted in each subplot of each block maintaining plant to plant distance of 75 cm and row to row 1 meter (Islam, 2006).

3.10 Intercultural operations

After 15 days of transplantation, one third Urea and Muriate of Patash were applied in ring method followed by weeding and irrigation. Remaining was applied after 35 and 55 days of transplantation.

3.11 Preparation of plant extract and their application

The plant extract treatments were used for the management of brinjal shoot and fruit borer in field level. All the studied treatments were applied in brinjal research field at 10 days interval from 20 DAT up to 50 DAT (four times).

Preparation of Tamarind fruit extracts

Initially 50 g ripe fruit of Tamarind were taken in a blender with 250 ml water and paste was made. Then 750 ml water was further added in these paste and mixed thoroughly filtered through fine mesh cloth . Thus the tamarind fruit extract @ 50 g L^{-1} water was prepared. The prepared tamarind extract was further use in brinjal field as per treatment by spraying.

Preparation of morning glory leaf extracts

Initially morning glory leaf extract (50 g leaves 250 ml water) was prepared by crushing the fresh leaves in water using a blender through straining and then cheesed. Then 750 ml water was further added in these paste and mixed thoroughly filtered through fine mesh cloth Thus the bon kolmi leaf extract was prepared @ 1:20 (50 g morning glory leaf: 1000 ml water). The prepared bon kolmi leaf extract was further used in brinjal field as per treatment by spraying.

Preparation Bullok's heart leaf extract

Initially stock Bullok's heart leaf extract (50 g leaves 250 ml water) was prepared by crushing the fresh leaves in water using a blender through straining and then cheesed. Then 750 ml water was further added in these paste and mixed thoroughly filtered through fine mesh cloth .Thus the ata leaf extract was prepared @ 1:20 (50 g ata leaf: 1000 ml water). The prepared ata leaf extract was further used in brinjal field as per treatment by spraying.

Preparation Neem leaf extract

Initially neem extract (50 g leaves 250 ml water) was prepared by crushing the fresh leaves in water using a blender through straining and then cheesed. Then 750 ml water was further added in these paste and mixed thoroughly and filtered through fine mesh cloth. Thus the neem leaf extract was prepared @ 1:20 (50 g neam leaf : 1000 ml water). The prepared neem extract was further used in brinjal field as per treatment by spraying.

Preparation Tobacco leaf extract

Initially tobacco leaf extract (50 g leaves 250 ml water) was prepared by crushing the fresh leaves in water using a blender through straining and then cheesed. Then 750 ml water was further added in these paste and mixed thoroughly filtered through fine mesh cloth . Thus the tobacco leaf extract was prepared @ 1:20 (50 g tobacco leaf : 1000 ml water). The prepared tobacco extract was further used in brinjal field as per treatment by spraying.

Preparation of Mahogony seed extract

Initially 50 g Mahogony seeds were taken in a blender with 250 ml water and made paste. Then 750 ml water was further added in these paste and mixed throughly filtered through fine mesh Thus the mahogony seed extract @ 50 g L^{-1} water was prepared. The prepared mahogony seed extract was further used in brinjal field as per treatment by spraying.

Preparation of Aktara 25 WG

Aktara 25 WG was dissolved in one liter of water and then stirred for 5 minutes and it was prepared for spray in brinjal field.

3.12 **Data collection**

3.12.1 Number of shoots plant^{-1}

Number of shoots plant^{-1} was recorded at harvest. Number of shoot was calculated by the sum of infested and healthy shoots from the randomly selected five plants and then converted into shoots plant^{-1}.

3.12.2 Number of infested shoot plant^{-1}

Number of infested or damaged shoots was recorded from the randomly selected five plants and then converted into infested shoots plant^{-1}.

3.12.3 Percentage of infested shoot

Percentage of infested shoot was recorded by the following formula:

$$\text{Infestation (\%)} = \frac{\text{Number of infested shoots}}{\text{Number of total shoots}} \times 100$$

3.12.4 Per cent reduction of shoot infestation over control

Percent reduction of shoot infestation over control was calculated by the following formula:

Percent reduction of shoot infestation over control =

$$\frac{\text{\% infestated shoot in control - \% infested shoot in the treatment}}{\text{\% infested shoot in control}} \times 100$$

3.12.5 Number of fruits plant^{-1}

Number of fruits plant^{-1} was recorded at harvest. Number of fruits was calculated by the sum of infested and healthy fruits from the randomly selected five plants and then converted into fruits plant^{-1}.

3.12.6 Number of infested fruits plant^{-1}

Number of infested or damaged fruits was recorded from the randomly selected five plants at harvest and then converted into infested fruits plant^{-1}.

3.12.7 Percentage of infested fruit

Percentage of infested fruit was recorded by the following formula:

$$\text{Infestation (\%)} = \frac{\text{Number of infested fruits}}{\text{Number of total fruits}} \times 100$$

3.12.8 Per cent reduction of fruit infestation over control

Percent reduction of fruit infestation over control was calculated by the following formula:

Percent reduction of fruit infestation over control =

$$\frac{\text{\% infestated fruit in control - \% infested fruit in the treatment}}{\text{\% infested fruit in control}} \times 100$$

3.12.9 Number of healthy fruit plant^{-1}

Number of healthy fruit was recorded from the randomly selected five plants at harvest and then converted into healthy fruit plant^{-1}.

3.12.10 Weight of fruits

Weight of fruits plant^{-1} was recorded at harvest. Weight of fruits data was calculated by the sum of infested and healthy fruits weight from the randomly selected five plants and then converted into kg plant^{-1}.

3.12.11 Weight of infested fruits plant^{-1}

Weight of infested or damaged fruits was recorded from the randomly selected five plants at harvest and then converted into weight of infested fruits plant^{-1}.

3.12.12 Percent weight of infested fruits

Percent weight of infested fruits was recorded by the following formula:

$$\text{Infestation (\%)} = \frac{\text{Weight of infested fruits}}{\text{Weight of total fruits}} \times 100$$

3.12.13 Yield plot^{-1} (g)

Fruit yield were recorded from the selected central 1 m^2 area of each plot. After harvesting the fruits weight was recorded and then converted in t ha^{-1}.

3.12.14 Yield increase over control

Yield increase over control was calculated by the following formula:

Yield increase over control =

$$\frac{\text{Fruit yield in treatment - Fruit yield in control}}{\text{Fruit yield in control}} \times 100$$

3.13 Statistical analysis

The data obtained from experiment on various parameters were statistically analyzed using MSTAT-C computer program (Russel, 1986). The mean values for all the parameters were calculated and the analysis of variance for the characters was accomplished. The significance of difference between pair of means was tested by Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

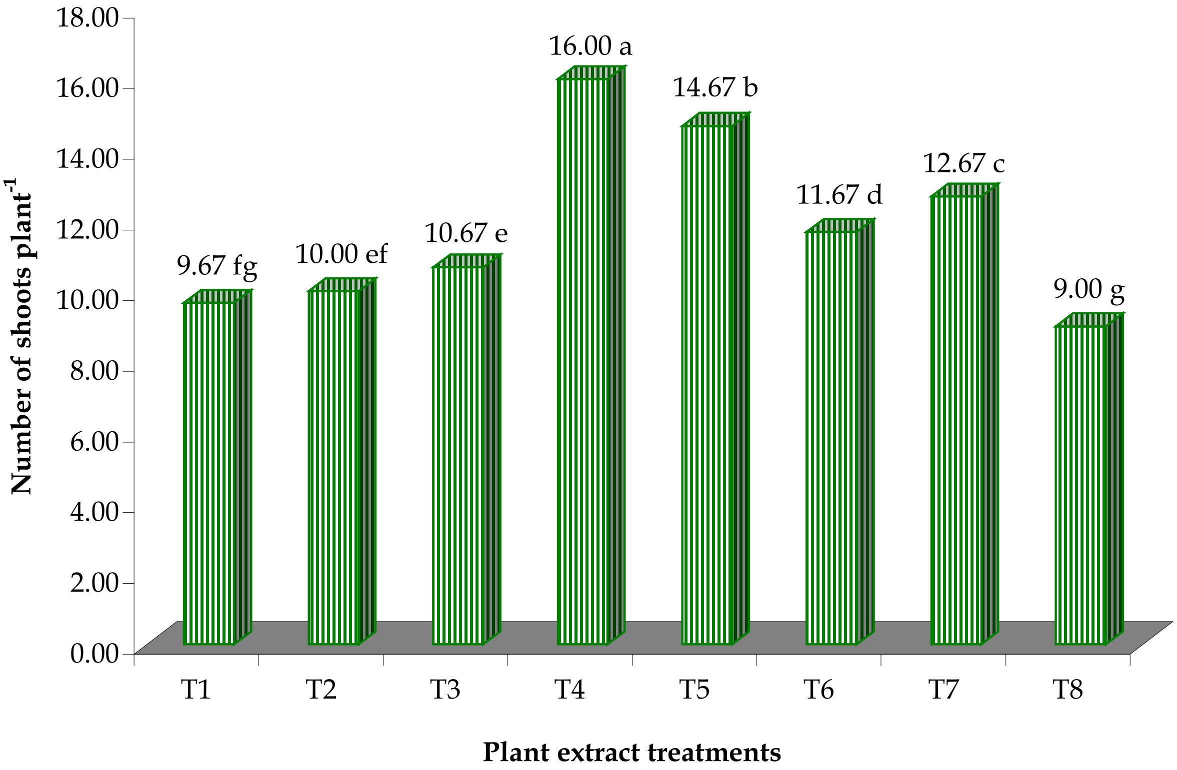
The experiment was conducted to evaluate the effect of some plant extracts aganist brinjal shoot and fruit borer. These compounds may act as effective insecticides against brinjal shoot and fruit borer in this study. Therefore in the present studies, effects of six plant extracts were evaluated in brinjal field and the results have been presented along with possible interpretations. A summary of the analysis of variance of the data for all the parameters was shown in Appendices IV to VI.

4.1. Effect of plant extracts on the management of brinjal shoot and fruit borer

4.1.1 Shoot characteristics

4.1.1.1 Number of shoots plant^{-1}

The various plant extracts used in this study were significantly influence the production of shoots plant^{-1} (Figure 1). Among them, neem leaf extract (T_4) were more effective than other plant extracts in producing more shoots (16.00 plant^{-1}) while Tobacco leaf extract (T_5) also found effective regarding shoot production (14.67 plant^{-1}). Among other treatments, the minimum number of shoots (9.00 plant^{-1}) were observed in untreated control plot while tamarind fruit extract (T_1) was nearly same in producing of minimum shoots of brinjal (9.67 plant^{-1}). These results indicated that neem leaf extract (T_4) were more efficient in producing more shoot than that of other plant extracts.



Various plant extracts including untreated control

Figure 1. Effect of various plant extracts on number of shoots plant^{-1}. Figures followed by same letter(s) are statistically similar as per DMRT at 5% level of significance.

T_1: Tamarind fruit extract @ 50 g L^{-1} water (T_1)

T_2: Morning glory leaf extract @ 50 g L^{-1} water (T_2)

T_3: Bullok's heart leaf extract @ 50 g L^{-1} water (T_3)

T_4: Neem leaf extract @ 50 g L^{-1} water (T_4)

T_5: Tobacco leaf extract @ 50 g L^{-1} water (T_5)

T_6: Mahogony seed extract @ 50 g L^{-1} water

T_7: Aktara 25WG @ 0.5 g L^{-1} water

T_8: Control

4.1.1.2 Number of infested shoots plant^{-1}

Significant variation were also found in the number of infested shoots plant^{-1} due to the use of various plant extract in this study (Figure 2). It was observed that among the plant extract treatments, neem leaf extract (T_4) was found most effective against brinjal shoot and fruit borer with minimum shoot infestation (0.33 plant^{-1}) which was closely followed by tobacco leaf extract (T_5) (0.67 plant^{-1}). The next in order of efficiency against brinjal shoot and fruit borer was Aktara 25WG (T_7) (1.00 plant^{-1})> Mahogony seed extract (T_6) (1.33 plant^{-1}) > Bullok's heart leaf extract (T_3) (1.67 plnat^{-1}) > Morning glory leaf extract (T_2) (2.00 plant^{-1}). Statistically similar as well as maximum shoot borer infestation (2.67 plant^{-1}) was found from the both control (T_8) and Tamarind fruit extract (T_1). These results revealed that neem leaf extract (T_4) was more effective in reducing shoot infestation and least incidence of shoot borer were found under this treatment compared to other treatments. Similar results were found by Dutta *et al*. (2011) who reported that significant variation in shoot infestation was evident among the effect of pheromone trap, mechanical control and application of peak neem (neem based insecticide). Similarly, Satpathy *et al*. (2005) also reported the similar findings incase of the conjugation of *T. chilonis* release and either shoot clipping + NSKE (4%) spray or endosulfan foliar spray @ 350 g ai ha^{-1}.

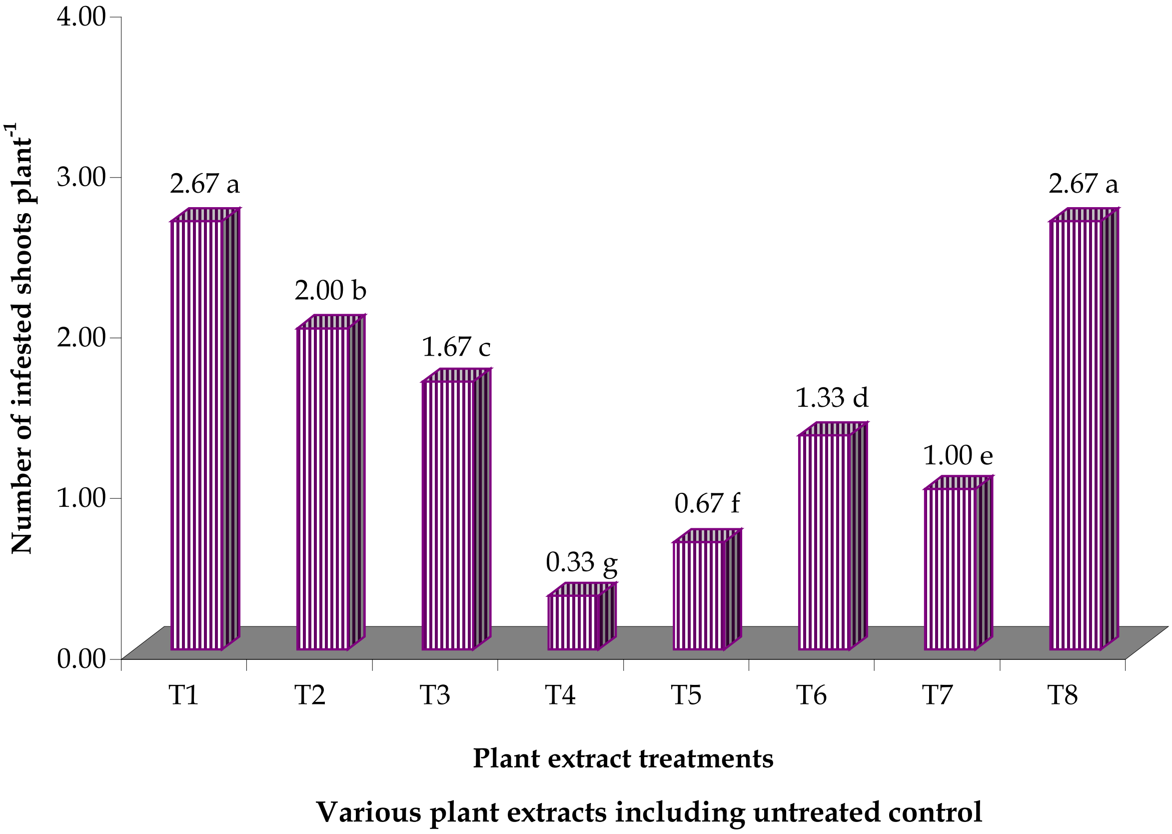


Figure 2. Effect of various plant extracts on number of infested shoots plant^{-1}. Figures followed by same letter(s) are statistically similar as per DMRT at 5% level of significance

T_1: Tamarind fruit extract @ 50 g L^{-1} water (T_1)

T_2: Morning glory leaf extract @ 50 g L^{-1} water (T_2)

T_3: Bullok's heart leaf extract @ 50 g L^{-1} water (T_3)

T_4: Neem leaf extract @ 50 g L^{-1} water (T_4)

T_5: Tobacco leaf extract @ 50 g L^{-1} water (T_5)

T_6: Mahogony seed extract @ 50 g L^{-1} water

T_7: Aktara 25WG @ 0.5 g L^{-1} water

T_8: Control

Plate 9. Photographs sowing the pupae and adults of *Leucinodes orbonalis*

Initial stage of brinjal shoot and fruit borer (BSFB) infestation

Mid stage of brinjal shoot and fruit borer (BSFB) infestation

Later stage of brinjal shoot and fruit borer (BSFB) infestation

Plate 10. Photograph showing shoot infestation by *Leucinodes orbonalis*

4.1.1.3 Percentage of shoot infestation

Percentage of shoot infestation by *L. orbonalis* was significantly differred due to application of various plant extract treatments (Table 1). The maximum infestation of brinjal shoot by BSFB was found in the untreated control plot. Among the plant extract applied, neem leaf extract (T_4) gave the maximum effectiveness in reducing the shoot infestation (2.22%) compared to other plant extracts. Untreated brinjal plant had the maximum shoot infestation (29.44%) by *L. orbonalis*. Neem leaf extract @ 50 g L^{-1} water (T_4) gave significantly lower rate (2.22%) of shoot infestation. Control treatment showed higher rate of shoot infestation by *L. orbonalis* in this study (29.44%). Similar results were also obtained by Singh *et al*. (2008) who found significant variation among alternative IPM tools *viz.*, pesticides against BSFB while mass trapping + neem oil spray + shoot clipping gave significantly lower shoot damage (29.44%) over untreated plots. Rosaih (2001b) also reported that NSKE 5% gave the least shoot damage (15.61%).

4.1.1.4 Protection percentage of shoot over control

Protection percentage of shoot *L. orbonalis* damge was calculated on the basis of control treatment. Among the plant extract treatments, more protection of shoot (92.45%) over control were obtained from neem leaf extract (T_4) followed by tobacco leaf extract @ 50 g L^{-1} water (T_5) (84.36%). The other treatments Aktara 25WG @ 0.5 g L^{-1} (T_7), mahogony seed extract @ 50 g L^{-1} water (T_6), bullok's heart leaf extract @ 50 g L^{-1} water (T_3), morning glory leaf extract @ 50 g L^{-1} water (T_2) and tamarind fruit extract @ 50 g L^{-1} water (T_1) gave 73.16, 60.43, 46.47, 31.62 and 6.90%, protection, respectively over control against the BSFB. However, tamarind fruit extract @ 50 g L^{-1} water (T_1) gave the lower protection in relation to untreated control treatment. These results revealed that the neem leaf extract (@ 50 g L^{-1} water) showed more significant effect on reduction of shoot damage than those of other treatments (Table 1). Similar findings were also obtained by Azad *et al*. (2012) who evaluated the effect of eight botanical extracts on pest control in brinjal field where they found that Marigold leaf extract showed good performance in protecting brinjal plant from

BSFB. Similar results were also obtained by Dutta *et al*. (2011) who found that simultaneous application of trap and peak neem provided 79.24% protection against shoot damage. Chatterjee (2009) also found that the application of Azadex (neem based insecticides) was most effective in reducing shoot damage (76.59%).

4.1.1.5 Number of healthy shoots plant^{-1}

Plant extract treatments were found to have profound effect on the production of healthy shoots of brinjal plants. Among the plant extracts, neem leaf extract @ 50 g L^{-1} water (T_4) was more effective to produce more healthy shoots (15.67 plant^{-1}) which was statistically differed from other treatment at 5% level. This was followed by tobacco leaf extract @ 50 g L^{-1} water (T_5) (14.00 plant^{-1}). The least number of healthy shoot (6.33 plant^{-1}) were recorded from untreated control plot which was statistically similar to that found in Tamarind fruit extract @ 50 g L^{-1} water (T_1) treated plot (7.00 plant^{-1}). These results indicated that neem leaf extract @ 50 g L^{-1} water (T_4) was more effective in producing more healthy shoot than that of other plant extract treatments (Table 1).

Table 1. Effect of various treatments (plant extracts) on infested and healthy brinjal shoot

Treatments	**Percentage of infested shoot**	**Protection percentage of shoot infestation over control**	**Number of healthy shoots plant^{-1}**
T_1	27.41 b	6.89	7.00 g
T_2	20.13 c	31.62	8.00 f
T_3	15.76 d	46.47	9.00 e
T_4	2.22 h	92.45	15.67 a
T_5	4.60 g	84.36	14.00 b
T_6	11.65 e	60.43	10.33 d
T_7	7.90 f	73.16	11.67 c
T_8	29.44 a	-	6.33 g
$LSD_{(0.05)}$	**1.89**	**-**	**0.98**
CV (%)	**7.24**	**-**	**5.48**

In a column, figures followed by same letter(s) are statistically similar as per DMRT at 5% level of significance

T_1: Tamarind fruit extract @ 50 g L^{-1} water (T_1)

T_2: Morning glory leaf extract @ 50 g L^{-1} water (T_2)

T_3: Bullok’s heart leaf extract @ 50 g L^{-1} water (T_3)

T_4: Neem leaf extract @ 50 g L^{-1} water (T_4)

T_5: Tobacco leaf extract @ 50 g L^{-1} water (T_5)

T_6: Mahogony seed extract @ 50 g L^{-1} water

T_7: Aktara 25WG @ 0.5 g L^{-1} water

T_8: Control

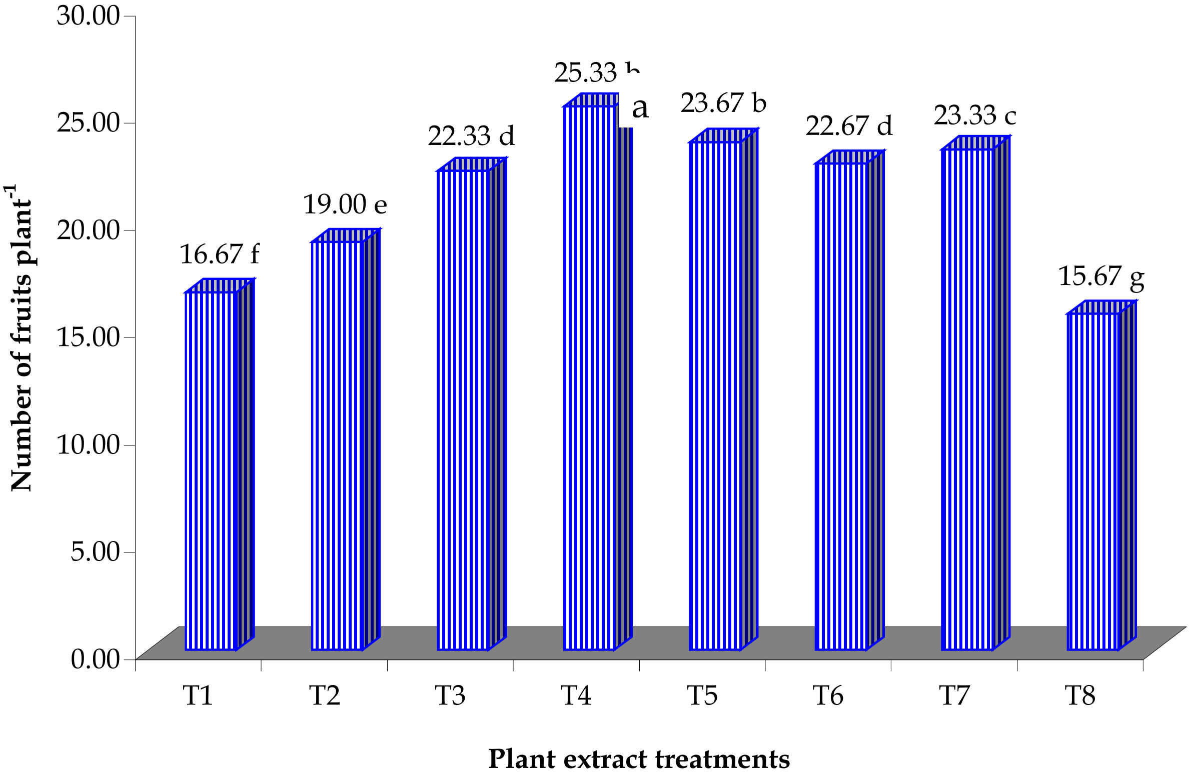
4.1.2 Fruit characteristics

4.1.2.1 Number of fruits plant^{-1}

The number of fruits plant^{-1} was significantly differed by the application of plant extract treatments in the present study. The maximum number of fruits (25.33 plant^{-1}) was obtained from the neem leaf extract @ 50 g L^{-1} water (T_4) treated plot which was statistically different from all other treatments. In contrast the minimum number of fruits (15.67 plant^{-1}) was harvested from the untreated control plot (Figure 3). These results revealed that neem leaf extract @ 50 g L^{-1} water (T_4) was more effective for producing more fruits than those of other plant extract treatments due to less infestation and production of healthy fruits (Figure 3).

4.1.2.2 Number of infested fruits plant^{-1}

Number of infested fruits plant^{-1} was statistically differed due to the effect of various treatments with plant extracts (Figure 4). Among the plant extract treatments, the minimum number of fruits infestation (2.33) was obtained from the neem leaf extract @ 50 g L^{-1} water (T_4) treated plot which was statistically differed from all other treatments (Plate 12). In contrast, untreated control treatment had the maximum fruits infestation (5.67) which was also statistically differed from all other treatments. However, Aktara 25WG @ 0.5 g L^{-1} (T_7) and tobacco leaf extract @ 50 g L^{-1} water (T_5) treated plot provided same results in terms of producing infested fruits plant^{-1} (2.67).



Various plant extracts including untreated control

Figure 3. Effect of various treatments with plant extract on number of fruits plant^{-1}. Figures followed by same letter(s) are statistically similar as per DMRT at 5% level of significance.

T_1: Tamarind fruit extract @ 50 g L^{-1} water (T_1)

T_2: Morning glory leaf extract @ 50 g L^{-1} water (T_2)

T_3: Bullok's heart leaf extract @ 50 g L^{-1} water (T_3)

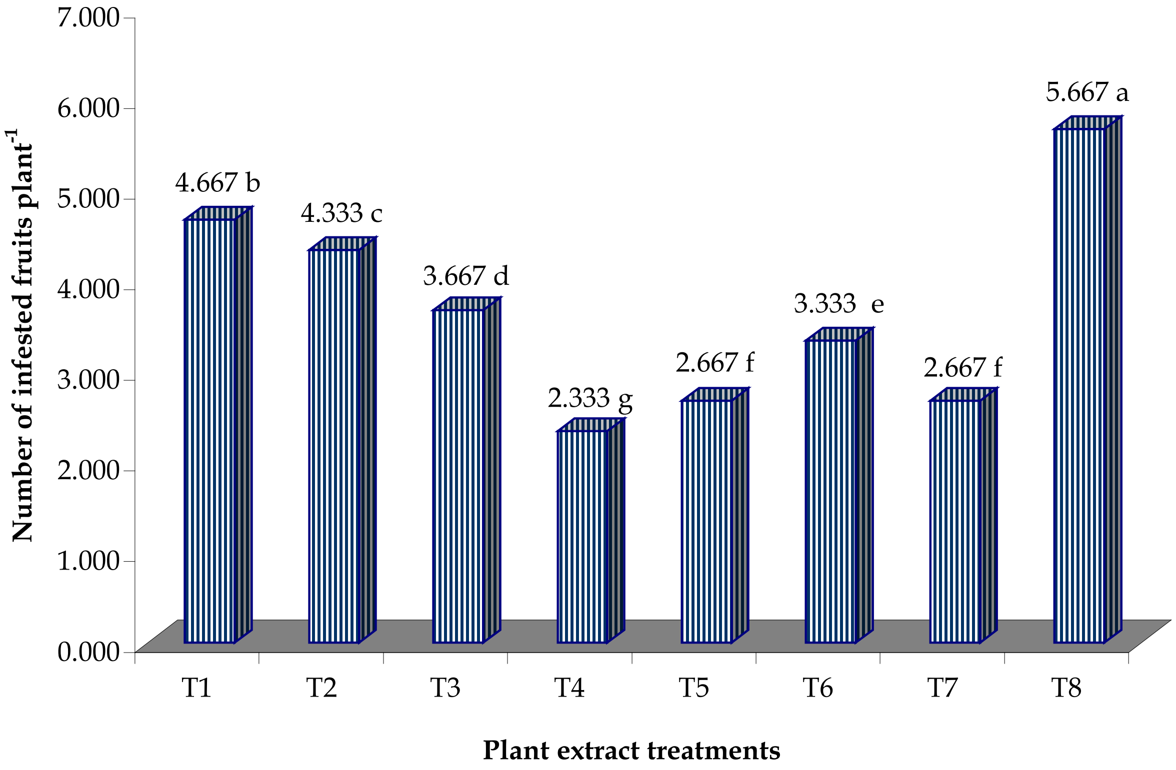
T_4: Neem leaf extract @ 50 g L^{-1} water (T_4)

T_5: Tobacco leaf extract @ 50 g L^{-1} water (T_5)

T_6: Mahogony seed extract @ 50 g L^{-1} water

T_7: Aktara 25WG @ 0.5 g L^{-1} water

T_8: Control



Various plant extracts including untreated control

Figure 4. Effect of various treatments with plant extract on number of infested fruits plant^{-1}. Bars followed by same letter(s) are statistically similar as per DMRT at 5% level of significance.

T_1: Tamarind fruit extract @ 50 g L^{-1} water (T_1)

T_2: Morning glory leaf extract @ 50 g L^{-1} water (T_2)

T_3: Bullok's heart leaf extract @ 50 g L^{-1} water (T_3)

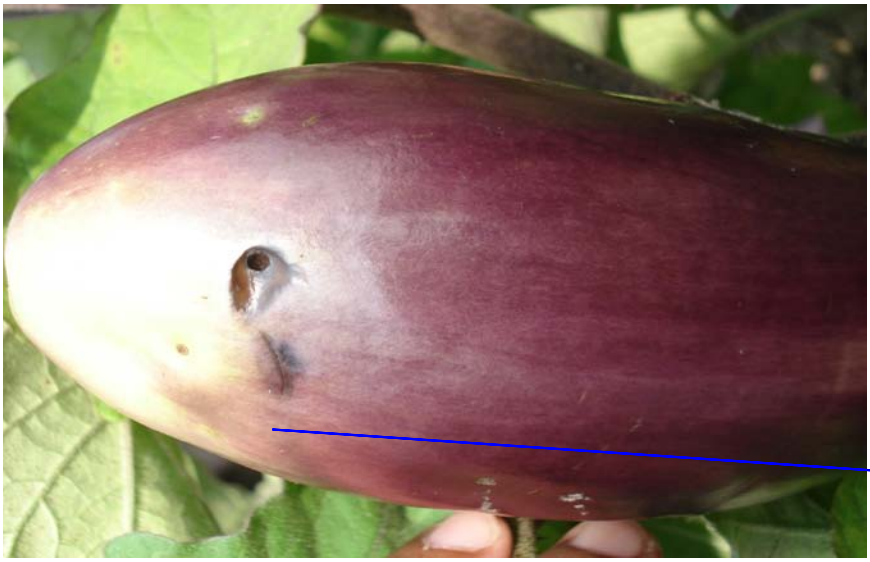
T_4: Neem leaf extract @ 50 g L^{-1} water (T_4)

T_5: Tobacco leaf extract @ 50 g L^{-1} water (T_5)

T_6: Mahogony seed extract @ 50 g L^{-1} water

T_7: Aktara 25WG @ 0.5 g L^{-1} water

T_8: Control



Initial view of fruit infestation

Pieces of infested or damage fruit

Plate 12. Photograph showing initial stage of fruit infestation (upper) and slices of infested fruits by *Leucinodes orbonalis*.

4.1.2.3 Percentage of fruits infestation

Application of treatments statistically differed on the rate of fruits infestation (Table 2). Among the treatments, the minimum rate of fruits infestation (9.30%) was observed in neem leaf extract @ 50 g L^{-1} water (T_4) treated plot while the untreated control plot had maximum fruit infestation (36.17%). Whereas all other treatments were statistically differed with each other except tobacco leaf extract @ 50 g L^{-1} water (T_5) and Aktara 25WG @ 2 g L^{-1} (T_7) treated plots where theyresulted statistically similar fruits infestation (11.36%). These result revealed that the treatment of neem leaf extract @ 50 g L^{-1} water (T_4) treated plot produced least rate of fruits infestation which might be due to the lower fruit infested by *Leucinodes orbonalis*. Satpathy *et al.* (2005) found that the fruit infestation in control plot was maximum (84.32%) compared to Endosulfan @ 350 g ai ha^{-1} and Neem seed kernel extract @ 4% (58.00 and 60.00%, respectively) treated plot which supported the results of the present study. Similarly, Ghatak *et al*. (2009) reported that two indigenous plant products viz., seed extracts of *Annona squamosa* (Annonaceae) and *Strychnos nuxvomica* (Loganeaceae) significantly reduced the fruit damage. Rosaih (2001b) also reported that NSKE 5% recorded least fruit damage (35.60%).

4.1.2.4 Protection percentage of fruits over control

Fruit infestation by brinjal shoot and fruit borer (*Leucinodes orbonalis*) and their protection percentage over control were investigated as resulted by the application of various treatments in the present study. Among the plant extract, more protection of fruits from infestation over control (91.26%) was obtained when the brinjal plants were treated by Neem leaf extract @ 50 g L^{-1} water (T_4). Among other treatments, the plant extract of tobacco leaf @ 50 g L^{-1} water (T_5), Aktara 25WG @ 0.5 g L^{-1} (T_7), mahogony seed extract @ 50 g L^{-1} water (T_6), bullok’s heart leaf extract @ 50 g L^{-1} water (T_3), bon kolmi leaf extract @ 50 g L^{-1} water (T_2) and tamarind fruit extract @ 50 g L^{-1} water (T_1) resulted 84.27, 83.59, 73.03, 67.22, 45.55 and 27.94% protection over control, respectively against the brinjal shoot and fruit borer. Whereas tamarind fruit extract @ 50 g L^{-1} water (T_1) gave the lower protection of fruits infestation compared to control treatment. The protection percentage range were $T_4 > T_5 >$

T_7> T_6> T_3> T_2> T_1 sequentially (Table 2). The present result was also agreed by the findings of Dutta *et al*. (2011) who found that the application of trap and peak neem afforded 47.70% protection against fruit damage. Similarly, Chatterjee (2009) found that the use of trap + azadex (neem based insecticides) afforded 39.06% protection against fruit damage. Singh *et al*. (2008) reported that mass trapping + neem oil spray + shoot clipping gave significantly higher protection resulting 38.0% improvement over untreated plots.

4.1.2.5 Number of healthy fruits plant^{-1}

Analysis of variance data on number of healthy fruits plant^{-1} was statistically differed by various treatments of plant extract in this study (Table 2). Among the treatments, the maximum healthy fruits (23.00 plant^{-1}) were harvested from the brinjal plot treated with neem leaf extract @ 50 g L^{-1} water (T_4) which was followed by tobacco leaf extract @ 50 g L^{-1} water (T_5) (21.00 plant^{-1}) and Aktara 25WG @ 0.5 g L^{-1} (T_7) (20.677 plant^{-1}) treated plots were statistically identical. On the other hand, untreated control plot of brinjal recorded the least number of healthy fruits (10.00 plant^{-1}) which was statistically differed from all other treatments (Plate 13). Neem leaf extract @ 50 g L^{-1} water (T_4) was more effective to suppress the brinjal shoot and fruit borer and produced more fruits accordingly lower infestation by BSFB ensured the higher production of healthy fruits.

Table 2. Effect of various treatments of plant extracts on fruit infestation

Treatments	Percentage of infested fruits	Protection percentage of shoot infestation over control	Number of healthy fruits plant^{-1}
T_1	27.95 b	27.92	12.00 e
T_2	22.76 c	45.55	14.67 d
T_3	16.38 d	67.22	18.67 c
T_4	9.303 g	91.26	23.00 a
T_5	11.36 f	84.27	21.00 b
T_6	14.67 e	73.03	19.33 c
T_7	11.56 f	83.59	20.67 b
T_8	36.17 a	-	10.00 f
$LSD_{(0.05)}$	**0.87**	**-**	**1.27**
CV (%)	**2.64**	**-**	**4.16**

In a column, Figures followed by same letter(s) are statistically similar by DMRT at 5% level of significance.

T_1: Tamarind fruit extract @ 50 g L^{-1} water (T_1)

T_2: Morning glory leaf extract @ 50 g L^{-1} water (T_2)

T_3: Bullok's heart leaf extract @ 50 g L^{-1} water (T_3)

T_4: Neem leaf extract @ 50 g L^{-1} water (T_4)

T_5: Tobacco leaf extract @ 50 g L^{-1} water (T_5)

T_6: Mahogony seed extract @ 50 g L^{-1} water

T_7: Aktara 25WG @ 0.5 g L^{-1} water

T_8: Control

Plate 12. Photograph showing fresh or healthy fruits before first harvest

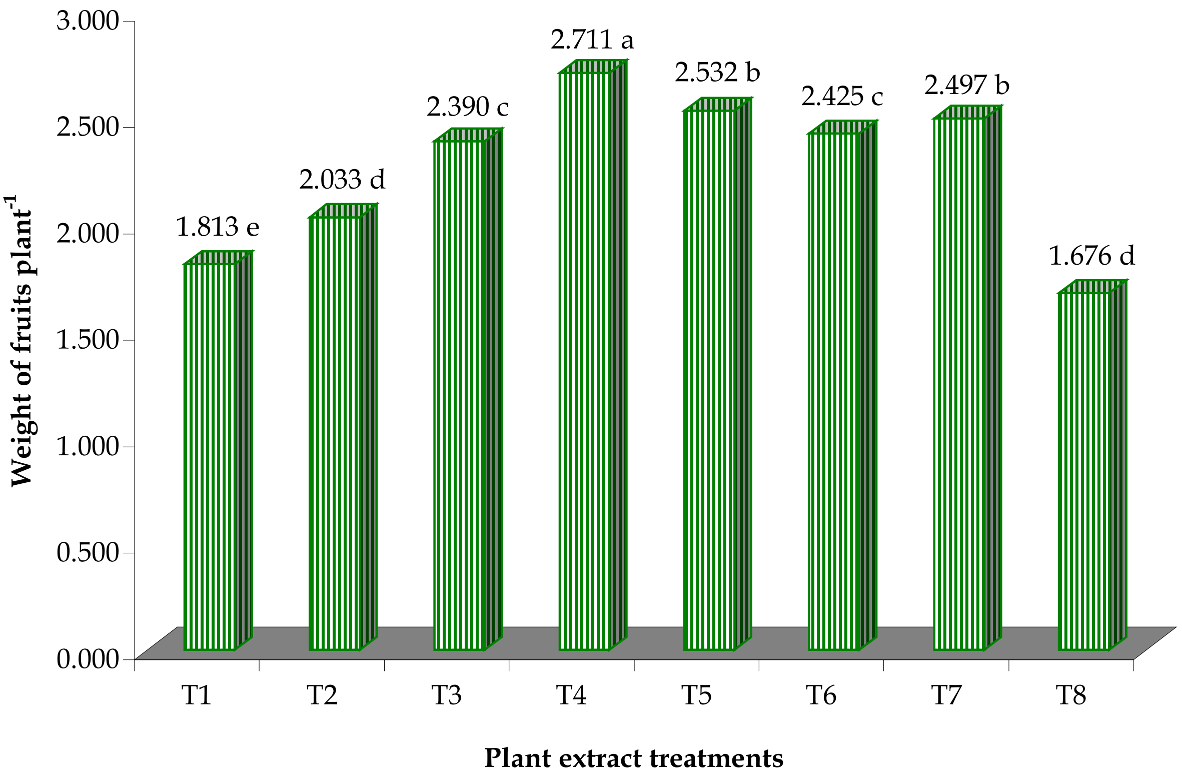
4.1.3 Fruit weight characteristics

4.1.2.1 Weight of fruits plant^{-1}

Analysis of variance data of total weight of fruits plant^{-1} showed significant variation among the treatments in this study (Figure 5). The highest weight of total fruits (2.711 kg plant^{-1}) was found from the neem leaf extract @ 50 g L^{-1} water (T_4) treated plot which was followed by tobacco leaf extract @ 50 g L^{-1} water (T_5), Aktara 25WG @ 0.5 g L^{-1} (T_7), mahogony seed extract @ 50 g L^{-1} water (T_6), bullok's heart leaf extract @ 50 g L^{-1} water (T_3) treated plot with a mean weight of 2.53, 2.50, 2.43 and 2.39 kg plant^{-1}, respectively were statistically similar. On the other hand, the lowest weight of total fruits (1.68 kg plant^{-1}) was obtained from the untreated control plots which was statistically identical (1.81 kg plant^{-1}) with that of tamarind fruit extract @ 50 g L^{-1} water (T_1). These results revealed that neem leaf extract @ 50 g L^{-1} water (T_4) were more effective for obtaining the maximum production of fruits plant^{-1}. This might be found due to the less infestation, more healthy shoots, and more fruits were produced in this treatment which ultimately increase fruits yield.

4.1.3.2 Weight of infested fruits plant^{-1}

Weight of infested fruits plant^{-1} showed significant variation among various treatments using plant extracts (Figure 6). The higher weight of infested fruits (0.606 kg plant^{-1}) was obtained from the untreated control plot which was statistically differed from all other treatments. However, tamarind fruit extract @ 50 g L^{-1} (T_1) and morning glory leaf extract @ 50 g L^{-1} (T_2) provided the statistically similar weight of infested fruit plant^{-1} (0.799 and 0.464 kg plant^{-1}, respectively). In contrast, the lowest weight of infested fruits (0.250 kg plant^{-1}) was obtained from the treatment T_4 (Neem leaf extract @ 50 g L^{-1}) while Tobacco leaf extract @ 50 g L^{-1} (T_5) and Aktara 25WG @ 0.5 g L^{-1} (T_7) gave statistically similar weight of infested fruits (0.285 kg plant^{-1}).



Various plant extracts including untreated control

Figure 5. Effect of various treatments of plant extracts on fruit production plant^{-1}. Bars with same letter(s) are statistically similar as per DMRT at 5% level of significance.

T_1: Tamarind fruit extract @ 50 g L^{-1} water (T_1)

T_2: Morning glory leaf extract @ 50 g L^{-1} water (T_2)

T_3: Bullok's heart leaf extract @ 50 g L^{-1} water (T_3)

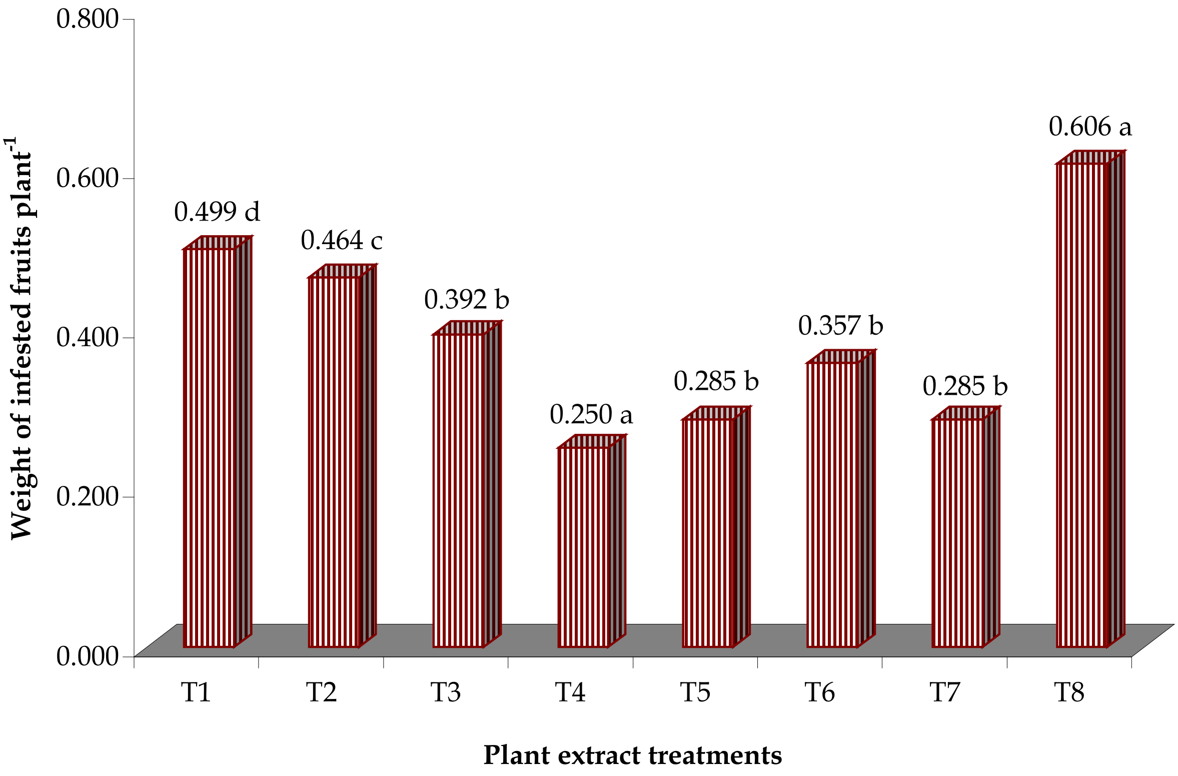
T_4: Neem leaf extract @ 50 g L^{-1} water (T_4)

T_5: Tobacco leaf extract @ 50 g L^{-1} water (T_5)

T_6: Mahogony seed extract @ 50 g L^{-1} water

T_7: Aktara 25WG @ 0.5 g L^{-1} water

T_8: Control



Various plant extracts including untreated control

Figure 6. Effect of various treatments of plant extracts on production of infested fruits plant^{-1}. Bars with same letter(s) are statistically similar as per DMRT at 5% level of significance.

T_1: Tamarind fruit extract @ 50 g L^{-1} water (T_1)

T_2: Morning glory leaf extract @ 50 g L^{-1} water (T_2)

T_3: Bullok's heart leaf extract @ 50 g L^{-1} water (T_3)

T_4: Neem leaf extract @ 50 g L^{-1} water (T_4)

T_5: Tobacco leaf extract @ 50 g L^{-1} water (T_5)

T_6: Mahogony seed extract @ 50 g L^{-1} water

T_7: Aktara 25WG @ 0.5 g L^{-1} water

T_8: Control

Rest of the treatments of plant extract such as T_3 and T_6 (Bullok's heart leaf extract @ 50 g L^{-1} water and Mahogony seed extract @ 50 g L^{-1} water) provided statistically similar weight of infested fruits (Figure 6).

4.1.3.3 Weight of healthy fruits plot^{-1}

Effect of various treatments of plant extract was significantly varied in weight of healthy fruits plot^{-1} at harvest (Appendix VI and Table 3). Among the plant extracts, significantly the higher weight of healthy fruits (2.645 kg plant^{-1}) were obtained from neem leaf extract @ 50 g L^{-1} water (T_4) treated plot which was followed by tobacco leaf extract @ 50 g L^{-1} water (T_5) (2.415 kg plant^{-1}) and Aktara 25WG @ 0.5 g L^{-1} (T_7) (2.377 kg plant^{-1}) and the later two were statistically identical. On the other hand, untreated control plants of brinjal provided the lowest weight of healthy fruits (1.150 kg plant^{-1}) which was followed by tamarind fruit extract @ 50 g L^{-1} water (T_1). Neem leaf extract @ 50 g L^{-1} water (T_4) were more effective in producing more healthy shoot and fruits which ensure the higher weight of healthy fruits.

4.1.3.4 Fruit yield

Effect of various treatments of plant extract was statistically varied in fruit yield (Table 3). Among the various treatments of plant extracts, significantly the highest yield of brinjal (36.15 t ha^{-1}) was harvested in neem leaf extract @ 50 g L^{-1} water (T_4) treated plot which was 61.74% higher yield over control. However, tobacco leaf extract @ 50 g L^{-1} water (T_5), Aktara 25WG @ 0.5 g L^{-1} (T_7), mahogony seed extract @ 50 g L^{-1} water (T_6) and bullok's heart leaf extract @ 50 g L^{-1} water (T_3) provided statistically identical but second higher yield of brinjal (33.76, 33.29, 32.33 and 31.87 t ha^{-1}, respectively) whereas their yield increased rate was 51.07, 48.98, 44.68 and 42.60%, over control respectively. Bon kolmi leaf extract @ 50 g L^{-1} water (T_2) and tamarind fruit extract @ 50 g L^{-1} water (T_1) treated plot produced statistically similar fruit yield but ranked third and fourth in yield of brinjal (27.11 and 24.1 t ha^{-1}, respectively) whereas the yield increased over control was 21.30 and 8.17%, respectively. On the other hand, the lowest yield of brinjal (22.35 t ha^{-1}) was obtained from the untreated control plots. The ranking order in sequence was $T_4 > T_5 > T_7 > T_6 > T_2 > T_1 > T_8$. These results revealed that neem leaf extract @ 50 g L^{-1} water (T_4) produced significantly the higher yield of brinjal in this study which might be found due to the minimum shoot and fruits infestation by BSFB and maximum healthy shoots and fruits as well as higher weight of total fruits $plant^{-1}$ resulting higher yield of brinjal in this study. Similarly, Azad *et al*. (2012) reported that out of six botanical extracts, neem leaf extract showed highest net production compared to untreated control. Similarly, Venkatesh *et al.* (2004) reported that among five organic manures, neem cake was the most effective to produce higher yield. Singh (2003) also found that the application of neem cake @ 20 q ha^{-1} + foliar spray of quinalphos 0.05% was effective in reducing the fruit borer incidence (20.63%) and increased the yield compared to control.

Table 3. Effect of various treatments of plant extract on different fruit weight parameters and their yield increase over control

Plant extract treatments	Weight of healthy fruits (kg plot^{-1})	Fruit yield (t ha^{-1})	Increase yield over control (%)
T_1	1.38 e	24.17 d	8.17
T_2	1.69 d	27.11 c	21.30
T_3	2.15 c	31.87 b	42.60
T_4	2.65 a	36.15 a	61.74
T_5	2.42 b	33.76 b	51.07
T_6	2.22 c	32.33 b	44.68
T_7	2.38 b	33.29 b	48.98
T_8	1.15 f	22.35 d	-
$LSD_{(0.05)}$	**0.15**	**2.12**	**-**
CV (%)	**4.16**	**5.89**	**-**

In a column, Figures followed by same letter(s) are statistically similar as per DMRT at 5% level of significance.

T_1: Tamarind fruit extract @ 50 g L^{-1} water (T_1)

T_2: Morning glory leaf extract @ 50 g L^{-1} water (T_2)

T_3: Bullok's heart leaf extract @ 50 g L^{-1} water (T_3)

T_4: Neem leaf extract @ 50 g L^{-1} water (T_4)

T_5: Tobacco leaf extract @ 50 g L^{-1} water (T_5)

T_6: Mahogony seed extract @ 50 g L^{-1} water

T_7: Aktara 25WG @ 0.5 g L^{-1} water

T_8: Control

From the above results, it was found that among the all applied plant extract treatments, neem leaf extract @ 50 g L^{-1} water (T_4) showed the superior performance to suppress the BSFB. It was also produced significantly the maximum healthy shoots and fruits as well as higher yield of brinjal compared to that of other studied plant extract treatments. However, untreated control plot resulted more shoots and fruits infestation by BSFB which increased the shoot and fruit damage and reduced the final yield of brinjal. Finally, it could be concluded that the use of neem leaf extract @ 50 g L^{-1} water would be highly effective to reduce the shoot and fruit infestation as well as to get higher yield of brinjal than that of all other plant extracts. Further study may be needed to ensure better performance of neem leaf extract @ 50 g L^{-1} water against BSFB suppression and better yield.

CHAPTER 5

SUMMARY AND CONCLUSION

The present study was conducted at the Research Field of the Department of Entomology, Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka-1207 during the period from November 2011 to June 2012 to study on the use of plant extracts for the management of brinjal shoot and fruit borer (*Leucinodes orbonalis*). The brinjal variety cv. Singhnath was used as planting materials for the present study. The present study was also consisted of eight treatments including control *viz.* T_1: Tamarind fruit extract @ 50 g L^{-1} water, T_2: Bon kolmi leaf extract @ 50 g L^{-1} water, T_3: Ata leaf extract @ 50 g L^{-1} water, T_4: Neem leaf extract @ 50 g L^{-1} water, T_5: Tobacco leaf extract @ 50 g L^{-1} water, T_6: Mahogony seed extract @ 50 g L^{-1} water, T_7: Aktara 25 WG @ 0.5 g L^{-1} and T_8: Untreated control. The seeds of the variety were collected from BARI. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications.

Analysis was done by using MSTAT-C package program whereas means were separated by DMRT at 5% level of probability.

Data were recorded on number of shoot plants $^{-1}$, number of infested shoot plants^{-1}, Percentage of infested shoot plants $^{-1}$, Number of healthy shoots plant^{-1}, number of fruits plants $^{-1}$, number of infested fruits plants $^{-1}$, Percentage of infested fruits plants $^{-1}$, Number of healthy fruits plant^{-1}, weight of fruits (kg plants $^{-1}$), weight of infested fruits (kg plants $^{-1}$), Percentage weight of infested fruits, weight of healthy fruits (kg plants $^{-1}$) and fruit yield (t ha^{-1}).

The results of the present study on various parameters of shoot and fruits number, their infestation percentage and the management performance and also on fruits yield were the determined after utilizing some plant extract treatments. The analysis of variance data regarding the studied parameters were significantly varied among the treatments of plant extract. Among the plant extracts, neem leaf extract @ 50 g L^{-1} water (T_4) treated plot recorded economically acceptable results among the studied parameters compared to all other treatments while the untreated control plots showed poor performance. As a results, neem leaf extract

@ 50 g L^{-1} water (T_4) showed the maximum number of total shoots (16.00 $plant^{-1}$), healthy shoots (15.67 $plant^{-1}$), total fruits (25.33 $plant^{-1}$), healthy fruits (23.00 $plant^{-1}$), higher weight of total fruits (2.711 kg $plant^{-1}$), healthy fruits (2.645 kg $plant^{-1}$) as well as the greater fruit yield (36.15 t ha^{-1}) whereas it was statistically differed from all other treatments of plant extract at 5% level. However, the results of untreated control were statistically similar to tamarind fruit extract @ 50 g L^{-1} water (T_1) treated plot in respect of shoots production (9.667 $plant^{-1}$), healthy shoots production (7.00 $plant^{-1}$), weight of total fruits (1.813 kg $plant^{-1}$) while other parameters were statistically differed from all other treatments at 5% level.

The lower number of infested shoot and fruit (0.33 and 2.33 $plant^{-1}$, respectively) and percentage (2.23 and 9.30%, respectively) were found in neem leaf extract @ 50 g L^{-1} water (T_4) treated brinjal plot while higher number of shoots and fruits (2.667 and 23.33 $plant^{-1}$) and higher percentage of shoot and fruit (29.44 and 36.17%, respectively) were recorded from untreated control plot. Protection percentage of shoot and fruit from BSFB infestation had also higher (92.45 and 91.26%, respectively) in neem leaf extract @ 50 g L^{-1} water (T_4) treated plot over control which was also increased the fruit yield over control (61.74%).The second higher protection of shoot and fruits were obtained by application tobacco leaf extract @ 50 g L^{-1} water (T_5) and third higher protection were recorded from Aktara 25 WG @ 0.5 g L^{-1} (T_7) treated plots. Similarly, the protection percentage range for both shoot and fruits were sequentially T_4> T_5> T_7> T_6> T_3> T_2> T_1. Similar ranks were also obtained in fruit yield. On the other hand, infested fruits weight and its percentage had also lower (0.250 kg $plant^{-1}$ and 9.303%, respectively) in neem leaf extract @ 50 g $L-^{1}$ water (T_4) treated plot while it was higher (0.606 kg $plant^{-1}$ and 36.17%, respectively) in untreated control plot.

Above results indicated that the treatment neem leaf extract @ 50 g L^{-1} water (T_4) showed the better performance to suppress BSFB among all applied plant extract treatments. Accordingly the maximum healthy shoots and fruits as well as higher yield of brinjal were obtained from this treatments compared to all other plant extracts tested.

Finally, it could be concluded that the use of neem leaf extract @ 50 g L^{-1} water would be highly effective to reduce BSFB infestation as well as to obtain higher yield of brinjal. Further study may be suggested to ensure its better performance commercially before recommending against *Leucinodes orbonalis* Guenee.

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APPENDICES

Appendix I. The morphological, physical and chemical properties of the experimental land

Morphological characteristics

Constituents	**Characteristics**
Location	Field Laboratory, Department of Agronomy, SAU, Dhaka
Soil Series	Tejgaon
Soil Tract	Madhupur
Land type	High
General soil type	Slightly acidic in reaction with low organic matter content
Agro-ecological one	“AEZ-28” of Madhupur Tract
Topography	Fairly level
Soil type and colour	Deep Red Brown Terrace Soil
Drainage	Moderate
Depth of inundation	Above the flood level
Drainage condition	Well drained

Physical properties of the soil

Constituents	Results
Particle size analysis	
Sand (%) (0.0-0.02 mm)	21.75
Silt (1%) (0.02-0.002 mm)	66.60
Clay (%) (<0.002 mm)	11.65
Soil textural class	Silty loam
Colour	Dark grey
Consistency	Grounder

Result obtained from the mechanical analysis of the initial soil sample done in the Soil Resources Development Institute (SRDI), Dhaka.

Chemical composition of the initial soil (0-15 cm depth)

Constituents	**Results**
Soil pH	5.8
Organic matter (%)	1.30
Total nitrogen (%)	0.101
Available phosphorus (ppm)	27
Exchangeable potassium (me/100 g soil)	0.12

Methods of analysis

Texture	**Hydrometer methods**
pH	Ptentiometric method
Organic carbon	Walkely-Black method
Total N	Modified kjeldhal method
Soluble P	Olsen method ($NAHCO^3$)
Exchangeable K	Flame photometer method (Ammonium)
Available sulphur	****

Result obtained from the mechanical analysis of the initial soil sample done in the Soil Resources Development Institute (SRDI), Dhaka.

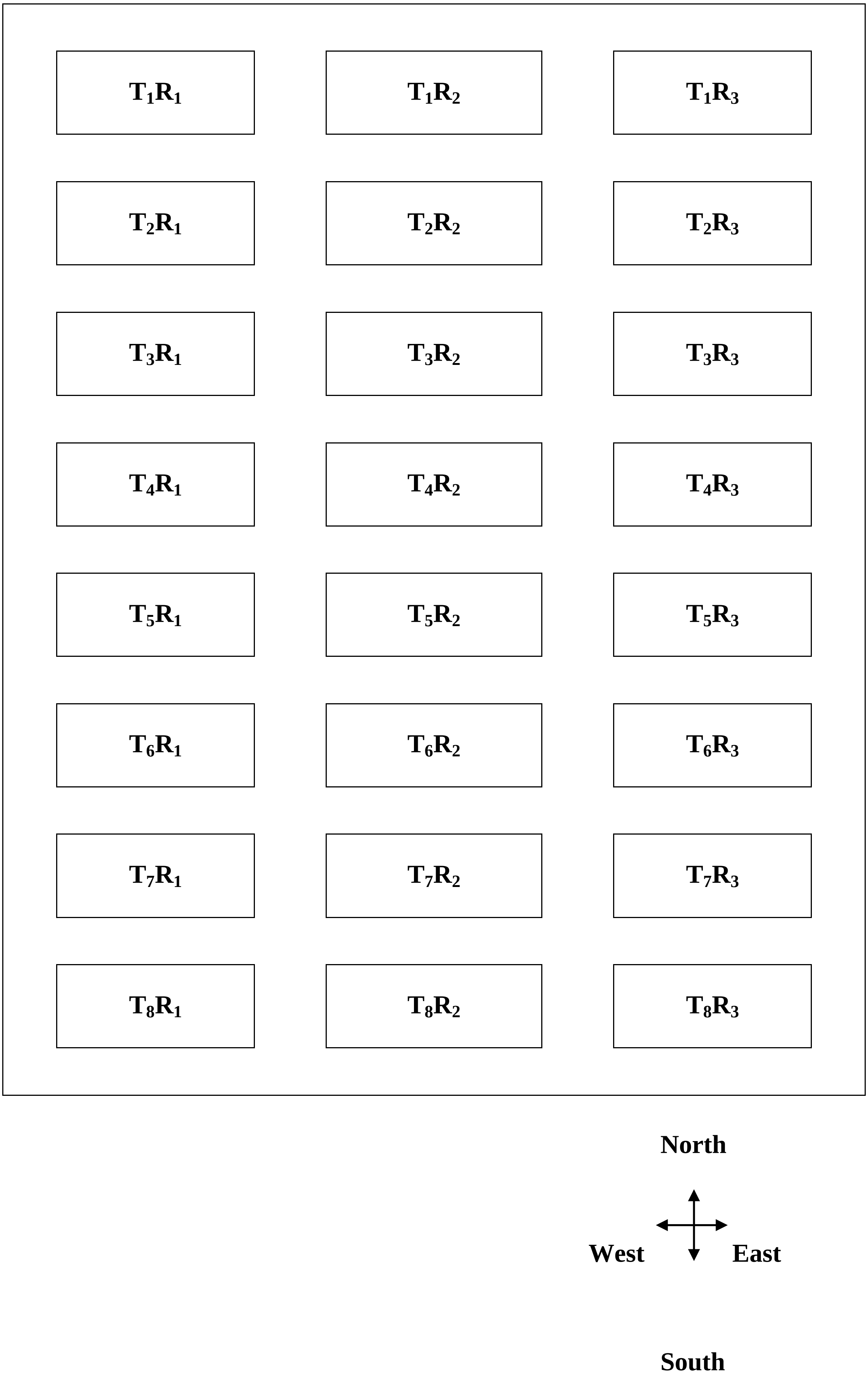
Appendix II. Monthly air temperature, rainfall, relative humidity and sunshine hours during the growing season (November 2011 to June 2012)

Month	Year	*Air temperature (^{O}C)			**Rainfall (mm)	*Relative humidity (%)	** Sunshine (hrs)
		Maximum	Minimum	Average			
November	2011	29.63	16.67	23.51	00.00	83.10	265.80
December	2011	25.52	15.70	20.61	00.00	87.55	142.80
January	2012	24.92	13.46	19.19	Trace	86.16	160.40
February	2012	28.77	15.33	22.05	Trace	73.57	223.40
March	2012	30.93	18.95	24.94	18.1	75.16	202.10
April	2012	28.53	16.85	22.69	19.58	79.58	119.65
May	2012	27.15	15.99	21.57	23.21	81.62	101.41
June	2012	26.54	14.61	20.58	21.54	82.35	111.26
Average		**27.75**	**15.95**	**21.89**	**13.74**	**81.14**	**165.85**

* Monthly average and ** Monthly total

Source: Bangladesh Meteorological Department (Climate division), Dhaka.

Appendix III: Lay out of the experiment



Legend:

Treatments: 8 (Eight); Replication: 3 (Three); Number of pot: 24

Length of plot: 5.0 m; Width of a plot: 3.0 m; Area of a plot: 15.0 m^2

Row to row distance: 1.0 m; plant to plant distance: 75 cm

Appendix IV. Analysis of variance (mean square) for various characters of shoot number and shoot infestation

Source of variation	Degrees of freedom	Number of shoots $plant^{-1}$	Number of infested shoots $plant^{-1}$	Percentage of infested shoot	Number of healthy shoots $plant^{-1}$
Replication	2	4.542	0.878	38.044	6.125
Factor A	7	18.661**	2.28**	309.54**	33.405**
Error	14	0.161	0.022	1.163	0.315

Appendix V. Analysis of variance (mean square) for various characters of fruits number and fruits infestation

Source of variation	Degrees of freedom	Number of fruits $plant^{-1}$	Number of infested fruits $plant^{-1}$	Percentage of infested fruits	Number of healthy fruits $plant^{-1}$
Replication	2	24.542	1.805	16.313	12.667
Factor A	7	37.31**	4.001**	266.542**	65.024**
Error	14	0.256	0.014	0.245	0.524

Appendix VI. Analysis of variance (mean square) for fruit weight characters

Source of variation	**Degrees of freedom**	**Weight of fruits (kg plant^{-1})**	**Weight of infested fruits (kg plant^{-1})**	**Weight percentage of fruits (kg plant^{-1})**	**Weight of healthy fruits (kg plant^{-1})**	**Fruit yield (t ha^{-1})**
Replication	2	0.376	0.029	16.051	0.168	31.256
Factor A	7	0.416**	0.046**	263.026**	0.86**	57.261 **
Error	14	0.01	0.001	0.216	0.007	3.315

****= Significant at 1% level of probability**