EVALUATION OF SOME SELECTED BOTANICALS AND CHEMICAL INSECTICIDES FOR THE MANAGEMENT OF BRINJAL SHOOT AND FRUIT BORER (*Leucinodes orbonalis* Guenee.)

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CERTIFICATE

This is to certify that the thesis entitled, **“Evaluation of some botanicals and chemical insecticides for the management of brinjal shoot and fruit borer (*Leucinodes orvonalis* Guenee.)”** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN ENTOMOLOGY,** embodies the result of a piece of bona fide research work carried out by **MAHMUD-AL-PARVEZ**, Registration No.08-3276 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated:

Place: Dhaka, Bangladesh

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Dedicated

To My

Loving and Honourable Parents.

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Abstract

An experiment was conducted at the experimental field of Sher-e-Bangla Agricultural University (SAU), Sher-e Bangla Nagar, Dhaka, to evaluate of some botanicals and chemical insecticides for the management of brinjal shoot and fruit borer (*Leucinodes orbonalis* Guenee.) during October, 2009 to April, 2010. The experiment comprised seven (7) treatments viz. (i) T_1 = Application of Mehogoni oil @ 5ml/L of water, (ii) T_2 = Application of Mehogoni oil @ 3ml/L of water, (iii) T_3 = Application of Neem oil @ 5ml/L of water, (iv) T_4 = Application of Neem oil @ 3ml/L of water, (v) T_5 = Application of Marshal 20 EC @ 2ml/L of water, (vi) T_6 = Application of Ripcord 10 EC @ 1ml/L of water and (vii) T_7 = Untreated control. Each application was done at 28 days after transplanting and repeated at 7days interval. The experiment was set up in Randomized Complete Block Design with three replications. Data on different growth and yield parameters were recorded and analyzed statistically. Results under the present experiment represented that the lowest shoot infestation (3.82%), lowest fruit infestation by number (12.29%) and by weight (8.73%), maximum total fruit yield (31.89 t/ha), lowest infested fruit yield (2.78 t/ha), highest healthy fruit yield (29.11 t/ha), highest fruit length (28.03cm), girth of fruit (12.82cm) and weight of edible portion of infested fruit (152.36 g), highest adjusted net return (Tk. 402540.00) and highest BCR (11.45) were achieved by Marshal 20EC @ 2ml/L of water at 28 days after transplanting and repeated 7 days interval (T_5) compared to all other treatments. The highest percent reduction of shoot infestation (72.18%), the highest percent (%) reduction of fruit infestation by number (62.02%) and by weight (72.12%), percent (%) increase of total yield (58.03%), maximum reduction of infested fruit yield (72.14%), maximum increase of healthy fruit yield (185.39%), highest percent (%) increase of fruit length (18.57%), girth of fruit (27.69%) and weight of edible portion per infested fruit (129.67%) over control were also achieved by Marshal 20EC @ 2ml/L of water at 28 days after transplanting and repeated 7 days interval (T_5). Thus it is said that among the treatments T_5 (Application of Marshal 20 EC @ 2ml/L of water after water 28 days after transplanting and repeated at 7days interval) showed the best performance for controlling brinjal shoot and fruit borer.

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CHAPTER I

INTRODUCTION

Bangladesh is predominantly an agricultural country where agriculture has been viewed as a fundamental contributor to the economy. Vegetable cultivation is one of the more dynamic and major branches of agriculture, and from the point of view of economic value of the produce, it is one of the most important. Vegetables are important for food security in Bangladesh. Nearly 100 different types of vegetables, comprising both local and exotic types, are grown in Bangladesh. Vegetables are the most important component of our food, and are rich in vitamins, minerals, fibers and plant proteins that are essential for human health. A number of vegetables are known to be as protective food items which prevent many diseases and ailments like, dislipidemea, cardiac disease, diabetes and constipation. Vegetables can be grown round the year, utilize homestead lands, provide high economic return and help in employment and income generation.

Vegetables crops assume great importance in Bangladesh in view of the serious problem of malnutrition that persists in this country. Majority of the population in Bangladesh suffer from severe malnutrition which has a negative effect on the development of the physical and mental growth. Severity of malnutrition and iron deficiency (anemic) is the highest among the children and female member of all age groups. Over 30,000 children become blind each year due to sever vitamin A deficiency. The average diet in the Bangladesh is deficient in almost all of the major nutrients, especially vitamins (vitamin A riboflavin, vitamin C and minerals).Vegetables are also rich in protein and calcium sources.

Vegetable are not merely items of food, they are also commodities for domestic and international trade and raw materials for the processing industry. Vegetables occupy 16% of the total cultivated land area of Bangladesh (BBS

2006). The production of vegetables has also increased from about 1606 metric tons in 2002-03 to about 2247 metric tons in 2007-08 (BBS 2009).

Depending on growing season in Bangladesh, vegetables are classified as winter (rabi- from October to March) and summer (kharif- from April to October) vegetables. Among the winter vegetables, brinjal, pumpkin, cabbage, cauliflower, tomato, bottle gourd, radish, country bean and spinach are important; and among the summer vegetables, pumpkin, brinjal, pointed gourd, lady's finger, ribbed gourd, snake gourd, bitter gourd, yard long bean, cucumber, ash gourd, amaranths and Indian spinach are important.

Brinjal or Eggplant, (*Solanum melongena* L.), is a typical solanaceous vegetable crop of sub-tropics and tropics in that its cultivation helps to generate income for farmers. This crop is especially important in South Asian countries like Bangladesh, India, Nepal, and Sri Lanka. This region accounts on over 678,000 ha, which is about 37% of the world eggplant area, with a production of 10.50 million tons (FAO, 2007). Eggplant is cultivated largely on small landholdings and commercial gardens where sale of its produce from frequent pickings through the prolonged harvest season generates valuable cash income to farmers. In the hot-wet monsoon season, when other vegetables are in short supply, eggplant is practically the only vegetable that is available at an affordable price for rural and urban people. According to BBS, 2008 data, brinjal (winter + summer) occupied the highest percentage (16.9%) of land under cultivation of vegetables in Bangladesh during the year 2005-06.

Brinjal or Eggplant, (*Solanum melongena* L.), the most popular and economically important vegetable in Asia, is available in Bangladesh throughout the year including the lean period. Sales of eggplant throughout the prolonged harvest season provide farmers with valuable cash income (Alam *et al*. 2003). This cash earning crop is damaged by more than a dozen insect pests, even from the nursery stage to harvest (Reghupathy *et al*., 1997). Among the insect pests infesting brinjal, the major ones are shoot and fruit borer, *Leucinodes orbonalis* (Guen.), whitefly, *Bemicia tabaci* (Genn.), leafhopper, *Amrasca biguttula biguttula* (Ishida), Epilachna beetle, *Henosepilachna vigintioctopunctata* (Fab.) and non insect pest, red spider mite, *Tetranychus macfurlanei* (Baker and Pritchard). Among these the most serious and destructive one is the Brinjal Shoot and Fruit Borer (BSFB), *Leucinodes orvonalis* (Guenee.) as it damages the crop throughout the year (FAO 2003; Rahman 2006; Nair 1986; Chattopadhyay, 1987)

Larval stage of this pest causes serious damage to shoots and fruits of eggplant. Larvae bore into the young shoots and feed on internal tissues resulting in wilting of the shoots, which reduces plant growth and number and size of fruits (Atwal and Dhaliwal 2007). They also bore into the fruits and feed on internal tissues making zigzag tunnels. The feeding tunnels are often clogged with frass, which makes even slightly damaged fruit unfit for marketing (Alam *et al.*, 2003). It causes considerable yield loss of eggplant every year throughout the cultivation areas. The extent of damage varied in different geographic locations and seasons of the year. The yield loss was reported to be as high as 70-92% (Krishnaiah and Vijay, 1975; Nair, 1995; Eswara Reddy and Srinivas, 2004). The fruit infestation ranged from 31-90% in Bangladesh (Islam and Karim 1993; Rahman 1997), 37-60% in different states in India (Dhanker 1988), and 50-70% in Pakistan (Saeed and Khan 1997)

Eggplant growers mostly depend on pesticides to combat this obnoxious pest. Available reports reveal that synthetic chemical insecticides dominate the other means for the control of it (Duara *et al*,. 2003; Singh and Singh 2003; Rahman *et al*., 2006). According to Alam *et al.*, (2006), over 90% of farmers applied more than 40 sprays per season (Gujrat) and 86% sprayed their crop two or three times a week (Uttar Pradesh) in India. A survey in Jessor district of Bangladesh reveals that 98% farmers relied exclusively on insecticides and more than 60% farmers sprayed their crop 140 times or more in the 6-7 months cropping season. The indiscriminate use of insecticides may result in a series of problems related to both loss of their effectiveness in the long run and certain externalities such as pollution and health hazards (FAO 2003). Moreover, improper doses resulted in high pesticide costs with little or no appreciable reduction in target pest populations (Alam *et al.*, 2003). Rather it may cause upset and resurgence due to destruction of natural enemies (Pedigo 2002, Debach and Rosen 1991). Pesticide use amounted to 38.8% of the total cost of production in brinjal (Alam *et al.*, 2006). Sub-lethal dose may induce resistance in target pest population.

So, under the circumstances, it becomes necessary to find out some eco-friendly alternative methods for the management of Brinjal shoot and fruit borer. The utilization of Botanicals or plant products can be eco-friendly components over chemical insecticides in formulating the integrated pest management approach for combating the pest. Hence keeping the above points in view, the present investigation was under taken with the following objectives.

i. To find out the level of infestation by BSFB both in shoot and fruit of brinjal.
ii. To find out the effectiveness of some selected botanicals and chemical insecticides against BSFB.
iii. To analyze the cost benefit ratio of different management practices.

CHAPTER II

REVIEW OF LITERATURE

Brinjal or eggplant (*Solanum melongena* L.) is an important solanaceous crop of sub-tropics and tropics. Egg plant is one of the most popular and economically important vegetables among small scale farmers and low income consumers of Bangladesh, especially during hot-wet summer when other vegetables are in short supply. It is cultivated in kitchen and commercial gardens during both Rabi and Kharif season in Bangladesh. This crop is infested by a large number of insect pests that cause considerable loss in the crop yield. Among them Brinjal shoot and fruit borer (BSFB), *Leucinodes orbonalis* Guenee is the most destructive pest of brinjal in Bangladesh (Alam, 1969; Nair 1986; Chattopadhyay, 1987; FAO 2003; Rahman 2006.) The damage caused by the pest either sporadically or in epidemic form every year all over Bangladesh. It inflicts damage to both shoots and fruits (Srinivasan, 2008). The infested fruit fetches low price and become unmarketable. Thus the crop is made totally unfit for human consumption.

There are different approaches are followed in Bangladesh for the management of this pest. One of them is clean cultivation involving removal of infested shoots and fruits. The other is the application of botanicals and chemical insecticides at 7-15 days intervals. Recently, a new technique named grafting is also suggested utilizing the wild *Solanum* as rootstock to reduce the infestation of shoot and fruit borer (Khorsheduzzaman *et al*., 1998). A number of insecticides have been found effective to control BSFB. Synthetic pyrethoids, Organophosphorus and Carbamate are widely used to control this pest. Synthetic pyrethoids have proved highly effective (Kuppuswamy and Balasubramanian, 1980; Nimbalkar and Ajri, 1981; Basha *et al*., 1982; Agnihotri *et al*., 1990). Carbamate has been reported effective in reducing the incidence of the pest at all stages of crop growth (Nath and Chakraborty, 1978).

Available literature relevant to this study has been made under the following headings:

2.1. General feature of brinjal shoot and fruit borer

2.1.1. Origin and Distribution

Eggplant fruit and shoot borer was first described as *Leucinodes orbonalis* by Guenée in 1854. It was designated as the type species of the genus by Walker in

1859. There are no known synonyms of *L. orbonalis*, but several other species of *Leucinodes* have been described. This insect belongs to family Pyralidae of the insect order Lepidoptera. The genus includes three species, *Leucinodes orbonalis* Guenee, *L. diaphana* Hampson and *L. apicalis* Hampson (Alam *et al.*, 1964). *Leucinodes orbonalis* is native to India but occurs in the Indian Sub-continent (Andaman Is., India, Pakistan, Nepal, Sri Lanka and Bangladesh), Far-East Asia (Hong Kong, China, Taiwan and Japan), Africa (Burundi, Cameroon, Congo, Ethiopia, Ghana, Kenya, Lesotho, Malawi, South Africa, etc.) (Veenakumari *et al*., 1995) and Saudi Arabia (Anonymous, 1982). Brinjal is severely attacked by shoot and fruit borer in the tropics but not in the Temperate zone (Yamaguchi, 1983). It was introduced into Spain from India during the Moorish invasion from where it spread throughout Europe then into America. The domesticated non-bitter types spread eastward into China by the fifth century BC from India (Yamaguchi, 1983).

2.1.2. Pest Status and Host Range

The brinjal shoot and fruit borer is the most destructive pest of brinjal (Alam and Sana, 1962; Butani and Jotwani, 1984; Nair, 1986; Chattapadhyay, 1987; Nayar *et al*., 1995). It was also found to attack shoots and fruit of tomato (Das and Patnaik, 1970), potato (*Solanum tuberosum* L.), green peas (*Pisum sativum* L.) (Hill, 1987; Atwal and Dhaliwal, 1997). Other wild species of *Solanum* are also attacked by this pest (Karim, 1994).

Isahaque and Chaudhuri (1983) observed for the first time that *Solanum nigrum, S. indicum, S. torvum, S. myriacanthum* and potato are alternative host-plant of the brinjal shoot and fruit borer in Assam. The larvae bored only into the shoots of the species.

2.1.3. Nature of Damage

Brinjal is severely attacked by shoot and fruit borer during the rainy and summer season. The losses due to its infestation are sometimes reported to be more than 90% (Kallo, 1988). The attack by the pest starts soon after transplanting the crop and continues till the last harvest of the fruits. The eggs are laid singly and deposited on the ventral surface of the leaves, shoots, flower buds, and petiole and occasionally on the fruit. Before fruiting stage, the larvae bore into the petioles and midribs of large leaves and also bore into the young shoots. Immediately after boring, the larvae close the entry hole with their excreta and feed inside (Butani and Jotwani, 1984). The infested shoots droops or wilts due to disruption of the vascular system and translocation of food materials. The time taken for the newly hatched larvae to move into the shoot is 3-4 hours (Alam and Sana, 1962). At later stage of the plant growth, the larvae bore generally through calyx and later into the flower buds and the fruits without leaving any visible sign of infestation and feed inside (Butani and Jutwani, 1984). The infested flower buds dry and shed. During fruiting period, the infestation of fruits is greater than that of the shoots because they prefer fruit than shoot (Alam and Sana, 1962).

When an infested fruit is cut open, dark excreta, moulds and sometime rotten portion is found. Often the infested fruits become unfit for human consumption and marketing. The full grown larvae come out through the exit hole and drop on the ground for pupation in the soil or plant debris, the larvae feed on the pith tissues of infested fruits by boring tunnels. The pest is reported to cause 1 to 16% damage to shoots and 16 to 64% to fruits in Bangladesh (Butani and Jutwani, 1984). The fruit yield losses incurred due to its infestation was estimated to be over 95% (Naresh *et al.*, 1986), more than 90% in Haryana (Kallo, 1988), India, and 86% in Bangladesh (Ali *et al.*, 1980). Hami (1955) reported that vitamin C (ascorbic acid) is reduced to the extent of 68% in infested fruit. This borer damaged 20.7%fruits and if only damaged portion of these fruits is discarded, the loss in weight comes to 9.7% (Peswani and Rattan Lal, 1964). Yield losses range 20-60% (Dhanker, 1988; Roy and Pande, 1994) and even higher (Lal, 1991).

2.1.4. Seasonal abundance

The seasonal abundance of the brinjal shoot and fruit borer varies considerably with varying climatic conditions throughout the year. Hibernation does not take place and the insects are found active in summer months, especially in rainy season. Maximum shoot and fruit infestation have been recorded during the months of January, May and June. They are less active during February to April (Alam, 1969). A study revealed that the population of the insects began to increase from the first week of July and peaked (50 larvae per 2m) during the third week of August. The population of this pest was positively correlated with average temperature, mean relative humidity and total rainfall (Shukla, 1989).

Alam (1969) observed that the duration of different stages last for longer periods, overlapping of generations were found. There are altogether five generations of the pest in a year of which three occur during May to October and two from November to April. Each generation covers about four to six weeks but in winter months it covers up to the extent of sixteen weeks during summer months.

There is a considerable mortality of larvae by rot caused by fungus during winter and by predatory black ants, *Camponotus compressus* F. during summer. Pupal mortality has been observed during rainy season due to attack of *Ichneumonid* parasitoid.

Alam (1969) found that the adult moths are also attacked by the black ant, *Camponotus compressus* F. Maximum population of adult moths has been observed in the month of December and April. According to Tripathi and Singh (1991), populations of BSFB on brinjal increased in the 1st and 3rd generations. Low population variation in minimum and maximum temperature but high relative humidity and heavy rain enhanced the population of the pest (Patel *et al.*, 1988).

The infestation of shoots began 30 days after transplanting, peaked in the 2nd week of September and reached zero on the 1st week of November. Fruit was infested from 3rd week of September and the infestation peaked in the 2nd week of November. On the summer crop, shoots were infested from the 3rd week of January and the infestation peaked in the 2nd week of February. Infestation of fruit peaked in the 1st week of April. Infestation levels were lower during the summer than during kharif (Pawar *et al.*, 1986).

2.1.5. Bionomics

The adult brinjal shoot and fruit borer moths are white and cryptic in nature (Alam, 1969) with 22 to 26 mm long at wing expanse (Butani and Jutwani, 1984). Head and thorax are variegated with black and brown color. The white fore wings have conspicuous black and brown patches and dots, the hind wings are opalescent with black dots along the margins (Butani and Jutwani, 1984). The margin of both the wings is provided with fine bristle like hairs. Mating takes place in the second night after emergence. The male dies after copulation and female after egg deposition. The eggs are laid singly and deposited on shoots, flower buds, petioles and on the ventral surface of the leaves, eggs are laid during the later part of the night and continues till the early hours in the morning (Alam, 1969).

Butani and Jutwani (1984) reported that a female lays an average of 250 eggs. The average number of eggs laid per female was 121.5 ± 0.449 and of these 79.24% were viable (Baang and Corey, 1991). On the other hand, the eggs are laid separately on the lower surface of young leaves (80-88%) and one female laid about 200 eggs (Yin, 1993). The hatching rate was 57.5-85.0% at 25-30°C. Alam *et al.*, (1969) observed that the egg measures on an average 0.44 mm x

0.32 mm with creamy white color and changed into yellow to yellowish orange as the development proceeds. The young larva on hatching measures 1.49 mm x 0.41 mm with slender abdomen tapers posteriorly. It is dull white color with yellowish tinge which later turns into creamy white (Alam *et al.*, 1964). The full-fed larva measures 16.3 mm x 3.16 mm in its widest part. The body is light pinkish in color with creamy tinge. The thoracic and the first three abdominal segments are more pinkish in color than those of the rest (Alam *et al.*, 1964).

After hatching the larva search for suitable place on the host for boring. During the fruiting stage of the plant, the larva prefers fruits than the shoots or other parts of the plant. A larva may destroy 4-6 fruits during its larval period (Atwal, 1976). The larva passes through 5 instars. Larval period varies from 12-15 days during the summer and 14-22 days in the winter. The full-grown larva passes through a pre-pupal period of 3-4 days (Butani and Jutwani, 1984; Alam and Sana 1962). Sandanayake and Edirisighe (1992) observed that the first instar larvae occurred in flower buds and flowers, while second instar larvae were present in all susceptible parts of the plant. Larvae remain to the shoots and fruits in their third and forth instars, while fifth instar larvae were found only in the fruits. The size of entry hole made by a larva was found to be a good indicator of its instar.

The full-grown larva comes out from the infested shoots or fruits through their feeding tunnel and pupates in ground litter usually 1-3 cm below soil surface within a boat-shaped, tough silken cocoon (Yin, 1993). During rainy season, pupation takes place on the stems or shoots or the dried leaves of the plants (Alam, 1969). The full-grown pupa measures 6.4 mm x 1.66 mm. The anal segment of the male pupa is devoid of bristles whereas, the female pupa has eight bristles with curved tips at the anal segment (Alam and Sana, 1962). The pupa is capable of surviving in temperature as low as 6.5°C the incubation, larval and pupal periods are 3-5, 12-15 and 7-10 days during the summer and 7-8, 14-22 and13-15 days in the winter respectively (Butani and Jutwani, 1984;

Alam and Sana, 1962). The full-grown larva shows a pre-pupal period of 3-4 days. The life cycle is completed in 34-59 days with five more overlapping generations per year (Alam, 1969). The insects are active throughout the year with more activity in the summer and rainy season than in the winter months (Alam and Sana, 1962). Yin (1993) reported that 1-6 generations in a year with over wintering pupa in China.

2.2. Management of Brinjal Shoot and Fruit Borer

2.2.1. Varietal Resistance

Resistant or relatively tolerant varieties of brinjal may be used as one of the components of Integrated Pest Management to manage the brinjal shoot and fruit borer (Islam and Karim, 1994). Cultivation of resistant variety can ensure the avoidance of pesticide use and therefore, save the environment i.e. natural enemies, health, soil micro flora and fauna etc. Alam *et al.*, (1994) conducted an experiment to compare the infestation of borer between non-grafted and brinjal plant using wild *Solanum* as rootstock. The lowest number of borer-infested fruits was recorded from the plants grafted on wild *Solanum*. They used wild *Solanum amphidiploid, S. sisymbriifolium* and *S. torvum* as rootstocks for grafting.

Baksha and Ali (1982) observed that out of 13 brinjal varieties and found that none of the varieties were resistant to *L. orbonalis*. They also reported that Baromashi, Jhumki, Indian and Bogra special were moderately tolerant to shoot infestation and Nayankajal, Singhnath, Japani, Jhumki, Indian and Baromashi were similarly tolerant to fruit infestation. Tolerance to both shoot and fruit infestation was highest in Jhumki and Baromashi.

Kabir *et al.*, (1984) reported that among 12 brinjal varieties for resistance to *L. orbonalis* in Bangladesh and they observed that the degree of resistance varied significantly. The variety Singhnath had the lowest rate of shoot infestation and also gave the highest yield, while Muktakeshi and Baromashi had the highest rate of infestation and gave lowest yield.

A large number of cultivated varieties of brinjal and related wild species of *Solanum* have been screened against shoot and fruit borer under natural and green house conditions and no resistance was found in cultivated varieties (Kallo, 1988).

Bazaz *et al.,* (1989) reported that the incidence of the pyralid brinjal shoot and fruit borer was lower on the brinjal plant cultivars SM-17-4 than on Punjab Camkila. They suggested that glycoalkaloids in association with phenolic compounds in SM-17-4 might be responsible for resistance to attack by *L. orbonalis.* Mote (1981) carried out a field studies to screen 32 varieties of brinjal for resistance to *L. orbonalis* and reported that the varieties Nimbkar green, Arka kusumkar, S.M. 213, Mukta keshi, Pusa kranti, A.C. 3698, S.M.2, Long green, Mysore, A-61 and Kalyanpur T-2 were rated as resistant on the basis of percentage of infested fruits. Panda *et al.*, (1971) tested 19 brinjal varieties against *L. orbonalis* under field condition and reported that Thorn Pendy, Black Pendy, H-165 and H-407 were highly resistant to be borer attack.

Gowda *et al.*, (1990) crossed *Solanum melongena*, GKVK, Composite-2 and P12 (susceptible) with *S. macrocarpon* which possessed resistance to *L. orbonalis.*

Dash and Shing (1990) tested nine brinjal plant cultivars in the field in Orissa during kharif 1985. None of the cultivars was free from attack by BSFB. Pusa purple cluster was the least susceptible variety with 18.7% of fruit being attacked.

Begum (1995) carried out a field trial at Regional Agricultural Research Station (RARS), Jamalpur, during Rabi season of 1994-95 with 24 brinjal varieties/cultivars to find out their tolerance to brinjal shoot and fruit borer. Among the tested varieties/cultivars, Jhumki-1 showed higher tolerance against this pest than others. The highest yield was obtained from Islampuri-1, although it had medium level of infestation (34% by number and 45% by weight). Higher percent infestation was found in Nayankajal (39%).

An experiment was conducted in Karnataka, India, in 1987-96 confirmed resistance in *Solanum macrocarpon* to *Leucinodes orbonalis* and also to *Asphondylia* sp. While the incidence of *L. orbonalis* on cultivated brinjal *(S. melongena)* varieties was 10-50%, less than 1% of *S. macrocarpon* fruits were damaged by *L. orbonalis* and *Asphondylia sp.* Resistance can be incorporated by crossing *S. macrocarpon* with brinjal (Kumar and Sadashiva, 1996).

Begum and Mannan (1997) carried out a field trial during 1996-97 with 24 brinjal varieties/cultivars against brinjal shoot and fruit borer and they reported that cultivars Jhumki-1 was more tolerant than others against this pest but higher yield was obtained from Muktakeshi

Panda (1999) conducted a field experiment on 174 brinjal cultivars for resistance to *L. orbonalis* at Bhubaneswar, India. None of the brinjal entries was immune to larval attack of shoots and fruits. The mean performance of shoot infestation varied from 1.61 to 44.11% and fruit damage varied from 8.5 to 100.0%. Maximum shoot damage was recorded at 75 DAT and 99-114 DAT in susceptible and resistant cultivars, respectively. Thus, early fruiting varieties are more liable to fruit attack by *L. orbonalis*.

Ten brinjal cultivars (Pusa Purple Cluster, Pusa Kranti, Pusa Purple Long, Neelum Long, Black Beauty, BR-112, Krishna, Kanahya, Pusa Purple Round and local variety) were screened for their resistance against the shoot and fruit borer *L. orbonalis* in a field experiment conducted in Rajasthan, India during the kharif season of 2000. All of the cultivars screened were susceptible to the pest. Pusa Purple Cluster, Pusa Kranti, Pusa Purple Long, Neelum Long, Black Beauty and BR-112 were least susceptible; Pusa Purple Round was susceptible; and the local variety, Krishna and Kanahya were highly susceptible (Yadav *et al.*, 2003).

Studies on the biophysical and histological characters of five brinjal genotypes showed that genotype with higher percent shoot pith area had higher degree of susceptibility to borer attack. Lignifications of tissue coupled with compact vascular bundles confer resistance against brinjal shoot and fruit borer. Plant with spready and semi-erect nature received lower shoot damage compared to the erect one. Long and compact seed-ring and closely arranged seeds in mesocarp exhibited resistance. Fruits with less seedless area suffered less fruit damage as compared to genotypes with more seedless area (Khorsheduzzaman, 2008).

The biochemical basis of host plant resistance for shoot and fruit borer of brinjal was investigated using selected genotypes from the back crosses involving cultivated brinjal varieties and Solanum viarum. The different levels of biochemical constituents namely peroxidase, poly phenol oxidase, total phenols, and solasodine contents were observed in genotypes derived from inter-specific crosses and their parents. A higher level of polyphenoloxidase activity was observed in interspecific cross F6 EP65 x S. viarum. There was a clear correlation between the levels of biochemical constituents and shoot and fruit borer incidence.

This study showed the biochemical parameters responsible for the resistance but showed as well the development of superior genotypes with resistance to shoot and fruit borer (Prabhu *et al.,* 2009).

2.2.2. Use of Natural Enemies in Biological Control

The effective control of the brinjal shoot and fruit borer by methods other than chemical insecticides has not yet been found. Khorsheduzzaman *et al.*, (1998) observed that sixteen parasitoids, three predators and three pathogens have so far been found as natural enemies of the brinjal shoot and fruit borer from all over the world. *Trathala flavo-orbitalis* cam. parasitizes the BSFB. Parasitism increased the host pupal period to 11 to 18 days, as compared to 6-14 days for healthy pupae; and parasitism varied from 3.57 to 9.06%. Adult parasitoids lived for 4-7 days in the laboratory (Mallik *et al.,* 1989).

Das and Islam (1984) reported that *Cremustus*, *Trathala flavo-orbitalis*, *Epitranus areolatus, E. giganticus, E. indictus, E. melongenus, E. rossicorpus* and *Pristomerus testaceus* as the parasitoids of BSFB while black ant, *Camponotus compressus* Fb. and spiders as predators.

Itamoplex sp. was reported from Kulu Valley, Himachal Pradesh, India where the winter temperature drops as low as – 8^0C. The parasitoid emerged from 9-15% of the larval cocoon of BSFB. *Itamoplex* (*Cruptus*) sp. was also recorded attacking a range of Lepidopteranian cocoon (Verma and Lal, 1985).

The brinjal shoot and fruit borer larval population peaked in May and the pest was active throughout the where *Trathala* sp. caused 12.90-18.18% parasitism of larvae. The parasitoid was active throughout the winter and summer seasons and preferred mature host larvae (Naresh *et al*., 1986).

Tewari and Sandana (1990) observed a larval ecto-parasitoid, *Bracon* sp. was found attached to the thorax of the host (*L. orbonalis*) larva in karnataka, india. It pupated in a silken cocoon inside the tunnel made by its host and parasitization ranged from 9.2 to 28.1%. It was regarded as promising parasitoid.

The efficacy of *Bacillus thuringiensis* subsp. kurstaki was studied with alternate applications of endosulfan/fenvalerate and methomyl under different spraying schedules in a field experiment with brinjal cv. KB 5 in Keonjhar, Orissa, India, during 1994. Spraying of Endosulfan (0.07%) at 30 days after planting (DAP) and Fenvalerate (0.02%) at 60 DAP resulted in the lowest fruit damage (33.3%) by *Leucinodes orbonalis* as compared with 64.2-65.1% damage in the untreated control and had the highest Benefit Cost ratio (40.3:1). The microbial insecticide *B. thuringiensis* subsp. *kurstaki* at a concn. of 0.05% was not found to be cost-effective against *L. orbonalis* under different spraying schedules (Patnaik and Singh, 1997).

Qureshi *et al.,* (1998) was conducted a field experiment in 1995 in Rajasthan, brinjal treated with Dipel 8 (formulation of *Bacillus thuringiensis* var. *kurstaki*) with or without insecticides. Treatment with 2 ml/litre of Dipel 8 significantly reduced fruit damage caused by *Leucinodes orbonalis* compared with the untreated control (8.78 vs. 12.34%) and produced higher fruit yield than the control (12.07 vs. 9.98 t/ha). Treatment with 1 ml Dipel 8 + 0.80 g Methomyl/litre water produced the lowest percentage of fruit damage and the highest fruit yield of 16.41 t/ha. During a survey for natural enemies of *Leucinodes orbonalis* on brinjal in India, Diadegma apostata was recorded from the pest for the first time (Krishnamoorthy and Mani, 1998).

Puranik *et al*., (2002) evaluated different B. *thuringiensis* (Bt) formulations in comparison with neem and chemical insecticides against brinjal shoot and fruit borer. Among the different treatments, five sprays of Dipel 8L @ 0.2 per cent at 10 days interval resulted in minimum shoot (9.56%) as well as fruit (11.78%) infestation and maximum yield of marketable fruits (196.96 q/ha) and proved to be the most effective treatment.

A field experiment was conducted by Elanchezhyan et al. (2008) to study the response of cultivars/ hybrids/ germplasm of brinjal to major insect pests and their natural enemies. The study revealed that the hybrid, Sweta was the best in reducing the shoot and fruit damage by *Leucinodes orbonalis* Guen. recording the mean shoot and fruit damage of 8.0 and 8.7 per cent (number basis) and population of spotted leaf beetle, Henosepilachna vigintioctopunctata Fab., ash weevil, Myllocerus spp. Guerin, mealybug, Coccidohystrix insolitus Green, aphid, Aphis gossypii Glover, leafhopper, Amrasca devastans Ishida and whitefly, Bemisia tabaci (Gennadius) recording 8.0, 0.0, 6.5, 6.3, 0.0 and 0.0 nos./ three leaves, respectively. The hybrids, Bejo Sheetal and Pusa hybrid-6 recorded high population of coccinellids, syrphids and spiders. The biochemical characters such as total sugars, total chlorophyll and moisture content were positively correlated with shoot damage while total phenols and ash content have negative correlation.

2.2.3. Sex Pheromone as a pest Management Technique

Sex pheromone is a chemical or a mixture of chemicals released by an organism that cause a specific reaction in the receiving organism of the same species through behavioural changes. Since pheromones are naturally occurring biological products, they are environmentally safe, non-target organisms are not affected, insects are less likely to developed resistance and moreover they are effective at ingredibly low concentrations (Kyoloniens and Beroza, 1982). Sex pheromone has been utilized in the insect pest control programs through population monitoring, survey, mass trapping and mating disruption. It has been reported that the sex pheromone have been detected from over 1000 species of insects and pheromone of about 280 species of insect pests are commercially synthesized and readily available for the control of insect pests in the world (Whitten, 1992). The virgin female of the brinjal shoot and fruit borer, *L. orbonalis* Guenee, secretes pheromone, which attracts male for mating. The compounds have been used effectively for pest management as monitoring adult population, mating disruption and attacking and killing the target pests in the trap (Bottrell, 1979).

Zhu *et al*., (1987) observed that the main component of the female sex pheromone of *L. orbonalis* Guenee, which is a serious pest of brinjal in various regions of china, was identified as (E)-11-hexadecanyl acetate. It was synthesized in the laboratory and tested in the field where more males were captured in traps baited with 300-500 mg of the compound than by 6 live females.

Srinivasan and Babu (2000) found that synthetic sex pheromone components A ((IIZ)-hexadecenyl acetate) and B ((IIZ)-hexadecen-1-ol), at 10, 50, 100, 200, 300, 400 and 500 mg alone, or in combination (A:B), at 100:5, 100:10, 100:20, 100:30, 100:50, 100:75, 100:100, 75:100, 50:100, 30:100, 20:100, 10:100, and 5:100 mg, were evaluated using water trough traps for moth (*L. orbonalis*) attraction and for use in monitoring pest incidence in brinjal in a field experiment conducted in Tamil Nadu, India. Component A at 300 mg resulted in the highest number of moths (86) trapped, while component B showed no attraction at any concentration. Among the A:B combinations, 100:50 mg showed the highest number of moths trapped (33).

Two studies were conducted at the experimental field of Entomology Division, Bangladesh Agricultural Research Institute (BARI), during October 2003 to March 2004 on different trap designs and trap heights for effective trapping of Brinjal Shoot and Fruit borer (BSFB) male moths. Among the three trap designs tested, Bangalore “open water trap” was the most effective in trapping BSFB moths, followed by BARI water trap and Indian funnel trap. Significantly higher number of BSFB moths were caught in the traps set below canopy level (0.5 m above ground) and at canopy level (1m above ground) than that of above canopy level (1.5m above ground level). Trap set below canopy level caught 5.44 times more BSFB male moths followed by traps set at canopy level (4.66 times) compared to those placed at upper canopy level (Anwar *et al.*, 2008).

The integrated pest management (IPM) strategy for the control of eggplant fruit and shoot borer consists of resistant cultivars, sex pheromone, cultural, mechanical and biological control methods. Eggplant accessions EG058, BL009, ISD006 and a commercial hybrid, Turbo possess appreciable levels of resistance to EFSB. Use of 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 EFSB 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. The profit margins and production area significantly increased whereas pesticide use and labor requirement decreased for those farmers who adopted this IPM technology. The efforts to expand the EFSB IPM technology to other regions of South and Southeast Asia are underway (Srinivasan 2008).

2.2.4. Integrated Pest Management

Integrated pest management packages include hand picking of infested shoots and fruits and dusting ash or application of insecticides and hand picking of infested parts were not found significantly effective in reducing the borer infestation over control. But the possibility of suppression of the brinjal shoot and fruit borer by cultural method, use of kerosene oil, botanical, grafting seedlings on wild *Solanum* and or use of selective chemicals may be explored (Anonymous, 1995b) the cause of reduced incidence of the brinjal shoot and fruit borer on grafted brinjal is not clear. But it is possible that there may be translocated of some substances toxic to the borer from rootstock to the scion.

Rahman *et al.*, (1996) obtained reduced rate of shoot/fruit infestation and increased yield by utilizing the IPM package consisting of Cymbush 10 EC sprayed on grafted brinjal and mechanical control on grafted brinjal.

Intercropping coriander (*Coriandrum sativum*) as a single line, double line or border crop with brinjal on infestation by *Leucinodes orbonalis* was compared with untreated and Cypermethrin-treated sole brinjal treatments during the 1995-96 and 1996-97 cropping season at Gazipur, Bangladesh. Fruits harvested from the untreated sole brinjal and brinjal-coriander border crop treatments a higher rate of infestation than those harvested from Cypermethrin-treated sole brinjal, brinjal-coriander single line intercrop and brinjal-coriander double line intercrop in both seasons. The highest Cost Benefit ratio was obtained from the plots which had single line coriander with brinjal as intercrop followed by brinjal-coriander double line intercrop, brinjal-coriander border crop and Cypermethrin-treated sole brinjal treatments. Intercropping coriander with brinjal might be an effective IPM component against *L. orbonalis* in reducing both fruit infestation and amount of insecticide used by farmers (Khorsheduzzaman *et al.,* 1997).

Mechanical control with neem oil and cymbush applied alternately at 7 days intervals gave the lowest fruit infestation (13.49%), which was followed by grafted plants with mechanical control + cymbush at 5% ETL (18.07%), and mechanical control + neem oil sprayed at 7 days intervals (22.68%) while the highest fruit infestation (45.54%) was found in the untreated control treatment (Khorsheduzzaman *et al*., 1998).

Studies were conducted on the effect of neem products on brinjal shoot and fruit borer *L. orbinalis*. Among the different neem products, neem oil 4 per cent recorded less fruit damage (9.07%) and higher yield (24.48 t/ha), NSKE 5 per cent was on par with it (Raja *et al*., 1998).
Krishnamoorthy and Krishnakumar (2001) from Indian Institute of Horticulture Research (IIHR) carried out a field experiment to study the effect of plant products on tomato fruit borer H. armigera. Different treatments tested included soil application of neem cake 250 kg/ha, neem seed powder extract 7 per cent, neem oil, pongamia oil, neem soap + pongamia soap all at 1 per cent. Among the different treatments tested, soil application of neem cake 250 kg/ha reduced the fruit borer incidence to 13.21 per cent as compared to 33.23 in untreated control.

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 + foliar spray of quinalphos

0.05 per cent was effective in reducing the fruit borer incidence (20.63%) and increased the yield (82.59 q/ha) compared to control (27.7q/ha). However, foliar spray of neem oil 3 per cent + basal application of neem cake @ 20 q/ha was on par with it.

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), farmyard manure and vermicompost (10.0 t/ha) alone and in combination with chemical fertilizer on *L. orbonalis*, whitefly and leaf hopper in brinjal. Among the cakes, neem cake was the most effective. Significantly higher yield (40.3 q/ha) was obtained from neem cake treated plots followed by vermicompost and castor cake treated plots.

Studies on the effect of organic amendments and indigenous products on brinjal shoot and fruit borer revealed that soil application of neem cake 0.5 t/ha + 50% RDF followed by foliar application of 5% NSKE – 3% vermi wash – 3% garlic chilli extract – 20% fermented botanical spray was more effective in reducing the shoot (15.64%) and fruit infestation (18.49%) and recorded highest marketable fruit yield (122.20 q/ha) being on par with vermicompost 1 t/ha + 50% RDF – 5% NSKE – 3% vermi wash – 3% garlic chilli extract – 20% fermented botanical spray shoot (17.79%), fruit infestation (22.38%) and marketable fruit yield of 110.40 q per ha (Jyoti D. Pareet, 2006.).
The effect of five different botanical extracts- tobacco, neem, garlic, eucalyptus and mehogony- on aphid population on yard long been was assessed in field , net- house and laboratory conditions at Khulna university, Bangladesh. Apheds were deliberately exposed to the above botanical extracts and then the numbers of live and dead aphids were counted. The botanical extracts showed significant effect on the numbers of live aphids. Tobacco leaf extract had inflicted consistently the maximum level of aphid mortality; about 74-90% of the aphids were killed by the treatment in different conditions. Killing about 53-64% of the aphids on treated plants, the extract of neem followed the extract of tobacco. Garlic extract shows similar performance to that of neem.

Eucalyptus and mehogony reduce aphid population but differed among the field, net-house and laboratory conditions. Contrasting to the case with aphid numbers, the botanical extracts did not affect the most common and recognized predators, ladybird beetles in the laboratory. Botanical extracts had significant effect on yield of yard long bean. Tobacco extract treated plants produce the greatest number, amount and biomass of yard-long beans; the treatment was followed by neem and garlic. The later two treatments did not show significant effect.

Oxymatrine (1.2 EC @ 0.2 per cent) and spinosad (45 SC @ 225 g a.i. /ha) 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 (D. Adiroubane and K. Raghuraman, 2008).

2.2.5. Control through Chemical Insecticides

It has been reported that of the available pest control techniques, chemical control measure are still the vital, prompt, cost-competitive, typically effective and valuable pest management tool (MacIntyre *et al.*, 1989). A wide range of insecticides as like Organophosphorus, Carbamates and Synthetic pyrethroids and varying spray formulations have been advocated from time to time against the BSFB (Yein, 1985 and Parkash, 1988).

Agnihotri *et al.*, (1990) observed the effectiveness of Cypermethrin, Fenpropat hrin, Carbaryl and Deltamethrin respectively and evaluated against *L. orbonalis* on two cultivars of brinjal, Pusa Kranti and Pusa Purple Long. Cypermethrin (0.01 %) and Deltamethrin (0.00125%) were the most effective. They found the residues on market size fruit declined to <0.01 ppm within 8 days for all insecticides except Cypermethrin when applied at >0.005 %, which left 0.03-0.04 ppm.

Field trials of Cypermethrin (0.01%), Fenvalerate (0.01%), Endosulfan (0.05%) and Carbaryl (0.2%) alone at half concentration mixed with Neemark (extract of *Azadarichta indica*) (0.5%) against the BSFB were carried out in Maharashtra, India in 1990-91.

During a 3-year study in Bangladesh on the effectiveness of some insecticides against *Leucinodes orbonalis* on brinjal, Carbofuran 3 G at 30 kg/ha applied every 20 days after transplanting showed the greatest effectiveness. The same compound applied once at flowering also gave good results, as did cypermethrin 10 EC at 1 ml/litre water applied at first signs of infestation, followed by 3 subsequent sprayings at 30-day intervals (Chowdhury *et al*., 1993).

Islam and Karim (1993) observed that eight Synthetic pyrethroids and one organophosphate tested against BSFB had insignificant effect in reducing the pest population. Although the insecticides were applied at the peak of adult emergence at an interval of not less than 21 days commencing from its first incidence. They also reported that the intensity of BSFB infestation in insecticide treated plots was as high as in control plots. This signals the possibility that the BSFB may have developed resistance against these insecticides.

Several insecticides were evaluated over 3 consecutive seasons in Bangladesh (Rabi 1990-91 at Joydebpur, and Rabi 1991-92 and Kharif 1992 at Jessore) to determine their efficacy to control *Leucinodes orbonalis* on brinjal. None had a significant effect in reducing the pest population and there was no difference between treatments and yield on either infested or uninfested plants during the Rabi season of 1991-92, and the Kharif season of 1992. Although the insecticides were applied at the peak of adult emergence at an interval of not less than 21 days commencing from 1st incidence, the intensity of the infestation in insecticide-treated plots was as high as that recorded from control plots. The results suggested that *L. orbonalis* may be developing resistance (Kabir *et al*., 1994).

In field trials in Maharashtra, India, in 1992-93, of 17 insecticidal control schedules tested against *Leucinodes orbonalis*, application of phorate 10G at 1.25 kg a.i./ha in a brinjal nursery at 15 days after sowing followed by three sprays of 0.05 per cent monocrotophos 36 WSC at 60, 80 and 100 days after transplanting was found most effective and economical in reducing shoot and fruit infestation and giving increased yield of marketable fruits (Deore and Patil, 1995).

A field experiment was conducted by Radhika *et al.,* (1997) in 1993 in Andhra Pradesh with brinjal Triazophos, Cartap or Methomyl were applied for the control of *Leucinodes orbonalis*. The application of 0.1% Triazophos on need basis (when >20% of the fruits were infested by the pest) produced the highest fruit yield and the highest return.

An infestation of brinjal fruit borer, *Leucinodes orbonalis*, was monitored throughout the growing season in Pakistan by picking infested and healthy fruits at ten day intervals. Infestation began soon after brinjal fruits were formed, peaking on 25 August then declining but remaining fairly constant (50-70%) during September-November, finally disappearing in the first week of December. Three Synthetic insecticides (including Voltage 50 EC [pyraclofos]) and one botanical insecticide (Nicotine sulfate 40 EC) were used for control. All gave a significant level of control for up to 18 days after application (Saeed and Khan, 1997).

A study on the use of insecticides for the management of brinjal shoot and fruit borer (*Leucinodes orbonalis*) was undertaken at Bangabandhu Sheikh Mujibur Rahman Agricultural University, Salna, Gazipur, Bangladesh, during the period from 29 October 1997 to 17 June 1998. Brinjal variety Singhnath was used in the field experiments. A number of treatments consisting mechanical (hand collection of infected shoots/fruits) and chemical (Cymbush 10EC [Cypermethrin] and/or Diazinon 60EC) were tested. The Benefit Cost ratio (BCR) was highest in plots treated with mechanical control + Cypermethrin. A similar BCR was achieved in the plots with weekly spraying of Cypermethrin. However, the weekly spraying involved applying 8 times more insecticide (Maleque *et al.,* 1998).

A study of the impact of the judicious use of chemical insecticides on natural enemies was undertaken in a brinjal field in Bangladesh. The results showed that lady bird beetles and spiders were seriously affected in the field where Cymbush 10EC [Cypermethrin] was applied at weekly intervals compared with fields where mechanical control and few sprays were applied, and unsprayed fields. The natural parasitism caused by an ichneumonid larval parasitoid of brinjal shoot and fruit borer (*Leucinodes orbonalis*) was found less affected in the mechanical control treatment with few spray applications compared with the field where Cymbush was applied weekly (Maleque *et al*., 1999).

An experiment was conducted by Islam *et al., (*1999) for the management of the brinjal shoot and fruit borer, *Leucinodes orbonalis* Guen. with insecticides applied at 10% action threshold level (ATL), at the peak of adult emergence (POAE), and applying mechanical control. The above treatments were compared with the scheduled spray of insecticides applied at weekly intervals and with an untreated control. The results indicated that when insecticide applications were restricted by applying at 10% ATL or at the POAE, the number of insecticide applications was reduced to 4-7 compared with the scheduled sprayed plots where 16 applications were required. Although the percent reduction in fruits damaged was higher in the scheduled sprayed treatments, the benefit cost ratio (BCR) (12-15) was about 3 times lower than in the ATL and POAE treated plots (28-38). In the mechanical control plots, the percent reduction in fruits damaged over the untreated control was only

9.33 and the percent yield increase over the untreated control was negative, the economic analysis gave a higher BCR of 14.61. The highest BCR of 37.77 was obtained in plots applied with Shobicron (mixture of Cypermethrin and Profenofos) at 10% ATL with only 3 applications. The hymenopterous parasitoid wasp of the brinjal shoot and fruit borer was less affected in the IPM intervention plots than in the scheduled spray plots.

An experiment was conducted by Biradar *et al.*, (2001) during the kharif and summer seasons of 1996-97, in Bijapur, Karnataka, India, to evaluate the efficacy of Cypermethrin 3 EC+Quinalphos 20 EC against the brinjal shoot and fruit borer, *Leucinodes orbonalis*. The treatments consisted of Cypermethrin 3 EC+Quinalphos 20 EC at 0.25, 0.50, 0.75 and 1.00 ml/litre, Cypermethrin 10 EC at 0.50 ml/litre, Quinalphos 25 EC at 2.00 ml/litre and an untreated control. The treatments were sprayed twice at 15-day intervals, with the first spray initiated at the peak of *L. orbonalis* incidence. All treatments recorded significantly lower fruit damage and higher fruit yield compared with the untreated control. Cypermethrin 3 EC+Quinalphos 20 EC at 1.00 ml/litre recorded the lowest percentage of fruit damage both on a number basis (29.5 and 22.4% after the first and second spray, respectively) and on a weight basis (25.3 and 20.2% after the first and second spray, respectively). This treatment also recorded the highest brinjal fruit yield of 8.9 q/ha.

A field experiment was conducted by Jat and Pareek (2001) to evaluate nine insecticides in controlling *L. orbonalis* in brinjal cv. Purple Round in Rajasthan, India, during the Kharif season of 1999 and 2000. The treatments were Endosulfan 35 EC at 0.07%, Malathion 50 EC at 0.05%, Carbaryl 50 WP at 0.2%, Neemgold 0.15 EC at 1.21 litre/ha, Nimbecidine 0.03 EC at 1.5 litre/ha, *Bacillus thuringiensis* (Bt) at 0.012%, Bt+Endosulfan (0.012%+0.035%), Bt+Carbaryl (0.012%+0.10%), Cypermethrin 25 EC at 0.007% and control. Nimbecidine was the least effective in controlling the pest and resulted in the lowest yield. The highest yield was obtained with Cypermethrin followed by Carbaryl and Endosulfan.

Ten combinations of insecticides (Carbofuran 3G at 0.5 kg a.i./ha, Malathion at 0.1%, Quinalphos at 0.05% and Teepol at 0.4%) and plant extracts (neem [*Azadirachta indica*] cake at 20 q/ha, karanj [*Pongamia pinnata*] cake at 20 q/ha, neem oil at 3% and karanj oil at 3%) were evaluated by Singh (2003) against the brinjal shoot and fruit borer, *Leuonodes orbonalis*, during 1997-98 and 1998-99 under agro-climate of Santhal Parganas (Bihar, India). The foliar application of quinalphos with basal application of neem cake reduced the incidence of borer and increased the yield of brinjal. The incidence and yield recorded in basal application of neem cake with foliar spray of neem oil was at par with combination of conventional insecticides. From environmental pollution point of view, neem products alone or in combination with conventional insecticide were advocated.

A field experiment was carried out by Duara *et al.*, (2003) in Jorhat, Assam, India during the rabi season of 2002 to evaluate the bioefficacy of Cypermethrin (0.003, 0.006 and 0.01%) and Fenvalerate (0.004, 0.008 and 0.015%), along with 0.07% Endosulfan, against brinjal shoot and fruit borer, *L. orbonalis*, on brinjal cv. Pusa Purple Round. All the insecticidal treatments gave effective control of shoot and fruit borers, and increased fruit yield over the control. However, no significant difference among the treatments was observed in terms of the reduction of shoot damage at 7 days after spraying. Plots treated with Cypermethrin at 0.006% and Fenvalerate at 0.015% recorded 28.25% shoot damage at 7 days after spraying. The highest yield (96.91 quintal /ha) was obtained with Cypermethrin at 0.006%, followed by Cypermethrin at 0.01% (93.83 quintal/ha). The yields obtained under both treatments were greater than that obtained under 0.07% Endosulfan (68.58 quintal/ha). [1 quintal=100 kg].

Fourteen insecticides in combination with Carbofuran, along with a control, were evaluated against the shoot and fruit borer of brinjal cv. Purple Long (*L. orbonalis*) in a field experiment was conducted by Singh and Singh (2003) in Meghalaya, India during the kharif season of 1994-95. Deltamethrin at 5 g a.i./ha was the most effective insecticide in controlling the borer in shoots followed by Fenvalerate at 25 g a.i./ha and Cypermethrin at 25 g a.i./ha, with shoot infestation ranging from 0.63-2.97, 0.98-4.26 and 1.13-4.56%, respectively. Among the conventional insecticides, Endosulfan at 0.25 kg a.i./ha and Fenitrothion at 0.25 kg a.i./ha, in combination with Carbofuran, were effective. Deltamethrin at 5 g a.i./ha, Fenvalerate at 25 g a.i./ha and Cypermethrin at 25 g a.i./ha were highly effective against the pest and resulted in higher yield of healthy fruits i.e. more than 1.75 kg/m^2 compared to other treatments. Among the conventional insecticides, Endosulfan, Monocrotophos and Fenitrothion at 0.25 kg a.i./ha, along with Carbofuran, were effective in controlling the pest and recorded yield of over 1.41 kg/m^2. Diflubenzuron at 37.5 g a.i./ha was the least effective in controlling the pest. Fenvalerate at 25 g a.i./ha, in combination with Carbofuran, was the most economical, with a Benefit Cost ratio (CBR) of 21:1 followed by Deltamethrin at 5 g a.i./ha with BCR of up to 18:1.

A field experiment was carried out in Bangladesh Sheikh Mujibur Rahman Agricultural University (BSMRAU) from November 2005 to April 2006 to evaluate the bioefficacy of different doses of flubendiamide, carbosulfan and abamectin against the brinjal shoot and fruit barer (BSFB). Carbosulfan 20EC @4.0 ml/l of water flubendiamide 24WG @ 0.7gm/l of water were found to be the most effective dose in reducing shoot (85.27% and 80.65%, respectively) and fruit infestation (84.85% and 84047% respectively). They also increase the production of healthy fruits (20.84 and 20.53 per plant respectively) and yield (20.84 t/ha and 2053 t/ha respectively) of brinjal. However, no significant difference was observed among the doses of carbosulfan 20EC @ 4.0 or 3.0 ml/l of water and flubendiamide 24WG 0.7 or 0.5 gm/l of water. Although the different doses of abamectin reduce the infestation of BSFB in comparison with control, its effectiveness was not considered satisfactory for recommendation (Ltif *et al.*, 2007)

The efficacy of 5 selected insecticides, two resistant lines and female sex pheromone was conducted by Rahman *et al.,* (2009) against Brinjal shoot and fruit borer (BSFB) (*Leucinodes orbonalis* Guenee) were evaluated in Gazipur and Jessore of Bangladesh during May to October, 2007. The treatments comprised T_1 = Cultivation of resistant line ISD006 without any insecticide use; T_2 = Cultivation of resistant line BL114 without any insecticide use; T_3 = Cultivation of susceptible variety Uttara without any insecticide use; T_4 = Use of female sex Pheromone placed at canopy and in the center of the plot without any insecticide use; T_5 = Spray Abamectin 100WSC @ 2 ml a.i. per litre of water; T_6 = Spray Nimbicidin @ 4 ml per litre of water; T_7 = Spray Suntap50 SP @ 5 mg per litre of water; T_8 = Spray Marshal 20 EC @ 1.5 ml per litre of water; T_9 = Spray Ripcord 10 EC @ 1 ml per litre of water and T_{10} = Untreated control. The effectiveness of the treatments in reducing shoot and fruit infestation by the BSFB did not differ significantly between the different locations, the shoot and fruit infestation was recorded at 19.90% and 16.16% respectively, which was 20.88% and 15.08% in Jessore. However, the effectiveness of the options in reducing the shoot and fruit infestation differed significantly with different treatments and all treatments except T_3 (the variety Uttara) significantly reduced shoot and fruit infestation over the control. Marshal 20 EC @ 1.5 ml per litre of water (T_8) performed the best ensuring the lowest shoot and fruit infestation (7.59% and 4.16% respectively) rendering 78.37% reduction in shoot and 88.06% and 88.99% reduction in fruit by number and by weight respectively, which was followed by Suntap 50 SP @ 5 mg per litre of water (T_7) that kept shoot and fruit infestation level at 10.77% and 11.53%, respectively. The T_8 also performed the best ensuring the highest healthy fruit yield (25.19 t /ha) as against only 2.09 t /ha infested fruit yield as compared to untreated control, which provided only 12.41 t /ha healthy fruit yield as against 9.91 t /ha infested fruit yield. The results thus indicated that in all aspects Marshal 20 EC (Carbosulfan) and Suntap 50 SP were most effective among insecticides followed by sex pheromone and other options.

An investigation was conducted by Latif *et al*., (2009) to evaluate the efficacy of flubendiamide as an IPM component for the management of brinjal shoot and fruit borer and eight IPM packages were evaluated. Among the different IPM packages, package 6 (mechanical control + potash @100 kg/ha + field sanitation in combination with flubendiamide 24WG applied at 5% level of shoot and fruit infestation) showed the better performance by reducing 80.63% fruit infestation over control and produced the highest number of healthy and total fruits/plant (25.0 and 27.20, respectively). The same package also increased 108.83% healthy fruit yield and decreased 74.13% infested fruit yield over control. The highest benefit cost ratio (5.53) was recorded in IPM package 2 (Potash @100 kg/ha + flubendiamide 24WG applied at 5% level of fruit infestation), where 9 sprays were required. The BCR of 4.12 and 4.00 was obtained in IPM package 6 and package 5 with 8 and 5 sprays, respectively. The results of this study suggested that application of flubendiamide at 5% level of fruit infestation in combination with mechanical control + potash @ 100 kg/ha + field sanitation may be used for the management of brinjal shoot and fruit borer.

The experiment was conducted by Latif *et al*., (2009) to determine the economic threshold for spraying of flubendiamide against the brinjal shoot and fruit borer. Flubendiamide was applied based on 10 thresholds including 2% shoot infestation, 5% shoot infestation, first fruit set + 2% fruit infestation, first fruit set + 5% fruit infestation, 2% fruit infestation, 5% fruit infestation, 2% shoot + 2% fruit infestation, 5% shoot + 2% fruit infestation, 5% shoot + 5% fruit infestation and schedule spray at 7 days interval. Flubendiamide applied at 2% shoot + 2% fruit infestation reduced the highest percent of shoot (87.46%) and fruit (81.43%) infestation over control and also produced the highest healthy (13.26 t/ha) and total fruit yield (13.77 t/ha) of brinjal and similar results were obtained for 5% fruit infestation. The highest benefit-cost ratio (BCR) was obtained (7.45) by application flubendiamide at 5% fruit infestation with 8 applications and that was the lowest (1.84) for schedule spray at weekly intervals with 16 sprays. Flubendiamide applied at 2% shoot + 2% fruit infestation had the BCR of 2.92 with the highest number of spray (19). Considering number of sprays, marketable yield of brinjal and also BCR, 5% fruit infestation was considered as economic threshold of flubendiamide spraying for the management of brinjal shoot and fruit borer.

Latif *et al.*, (2010) observed the Efficacy of nine insecticides against shoot and fruit borer, *Leucinodes orbonalis* Guenee (Lepidoptera: Pyralidae) in eggplant Shoot and fruit borer, *Leucinodes orbonalis* Guenee, is a serious pest of eggplant (*Solanum melongena* L.). Management practices of this obnoxious pest are limited to frequent spray of chemical insecticides. Due to increasing levels of resistance of *L. orbonalis* to different insecticides there is an urgent need to test new chemicals. In this study, nine insecticides such as azadirachtin 0.03EC, abamectin 1.8EC, flubendiamide 24WG, chlorpyriphos 20EC, cartap 50SP, carbosulfan 20EC, thiodicarb 75WP, cypermethrin 10EC, and lambdacyhalothrin 2.5EC belonging to different chemical groups were tested against eggplant shoot and fruit borer in laboratory and field. In laboratory trial, carbosulfan and flubendiamide showed the highest toxicity against fourth instar larvae of *L. orbonalis* after 24 and 48 h of exposure, respectively. In field trials, they reduced more than 80% shoot and fruit infestation in winter, and 80% shoot and 70% fruit infestation in summer over control. Carbosulfan protected the highest amount of healthy fruit yield in both cropping seasons. Flubendiamide also showed the similar efficacy. Cartap and thiodicarb were moderately effective in both the seasons. Efficacy of cypermethrin and abamectin was moderate in winter but low in summer. Lambdacyhalothrin and chlorpyriphos although reduced shoot and fruit infestation of eggplant and protected higher yield as compared to control, their effectiveness was not satisfactory. The performance of azadirachtin against the pest both in the laboratory and field trials was the poorest while that of carbosulfan and flubendiamide was the best. Thus, it is suggested that carbosulfan and flubendiamide may be used for the control of *L. orbonalis* in eggplant.

CHAPTER III

MATERIALS AND METHODS

The present experiment was carried out to evaluate some selected botanicals and chemical insecticides for the management of brinjal shoot and fruit borer (BSFB) comprising two selected botanicals with different doses and two insecticides in the experimental field of Sher-e-Bangla Agricultural University (SAU), Sher-e Bangla Nagar, Dhaka, during October, 2009 to April, 2010. The materials and methodology of the study described below under following sub-headings.

3.1. Location

The study area is situated at 23º 74′ N latitude and 90º 35′ E longitude with an elevation of 8.2 meter from sea level (Fig.1).

3.2. Climate

The climate of the experimental site is subtropical, characterized by heavy rainfall during the month of October 2009 to July 2010. Weekly maximum and minimum temperature, relative humidity, total rainfall during the study period were collected from the Bangladesh Meteorological Department (Climate Division) and have been presented in Appendix I.

3.3. Soil

The soil of the experimental area belongs to the Modhupur Tract (UNDP, 1988). The analytical data of the soil sample collected from the experimental area were determined in the SRDI, Soil Testing Laboratory, Khamarbari, Dhaka have been presented in appendix II.

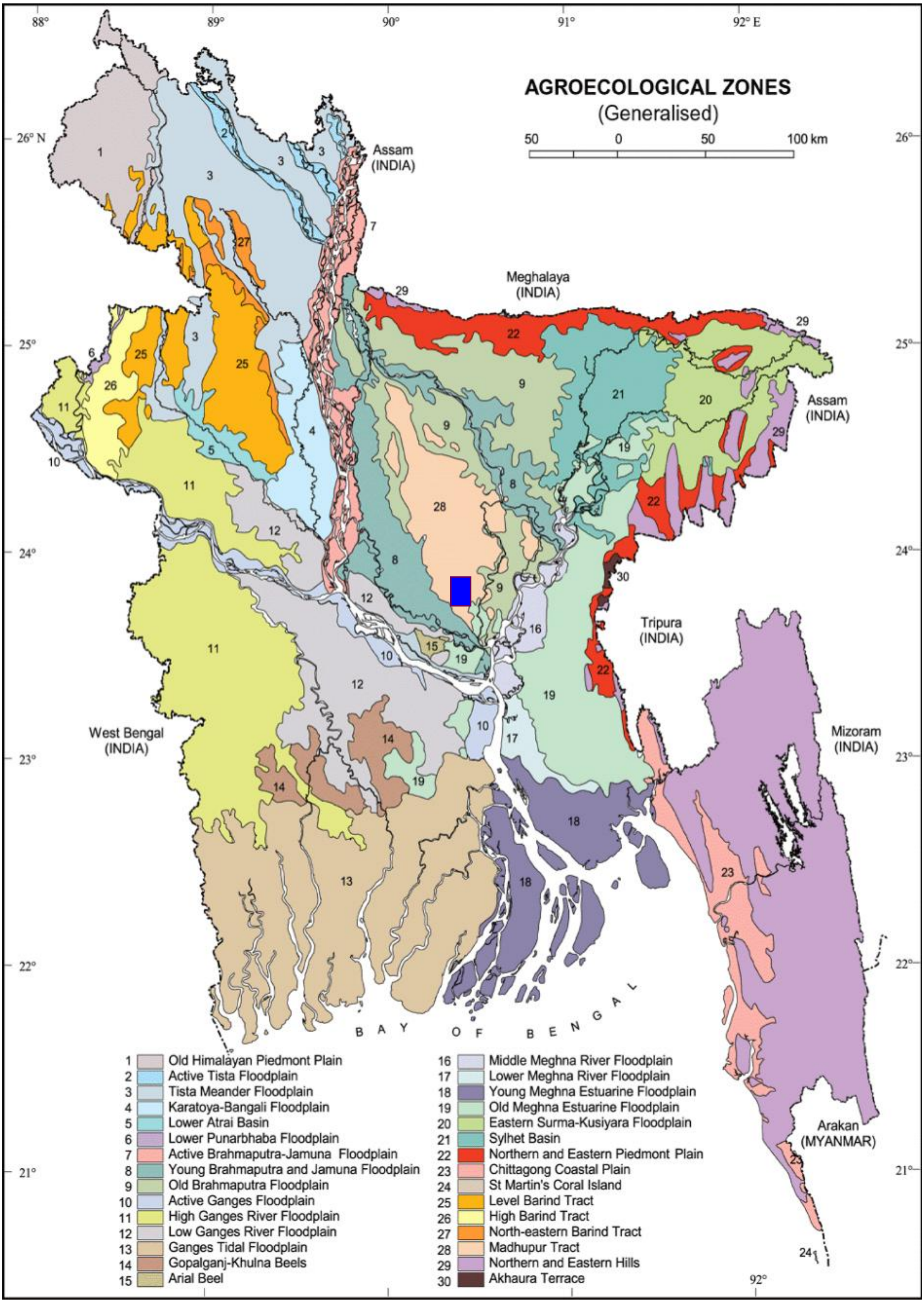

Figure 1. Location of experimental field

The experimental site was a medium high land and pH of the soil was 5.6. The morphological characters of soil of the experimental plots as indicated by FAO (1988) are given below –

AEZ No. 28
Soil series – Tejgaon
General soil- Non-calcarious dark grey.

3.4. Design of Experiment

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh.

3.5. Land preparation

The land was prepared by harrowing followed by ploughing, cross- ploughing and leveling. Cow-dung and other chemical fertilizers were applied as recommended by Rashid (1993) for eggplant at the rate of 15 tons cow-dung and 250, 50 and 125 Kg urea, T.S.P and MOP, respectively per hectare. The full dose of cow-dung, TSP and a half of MOP were applied as basal dose during land preparation, the entire dose of urea and rest of MOP was applied as top dressing. The first top dressing with one third of urea was made at 20 days after transplanting followed by second top dressing comprising one third of urea and one fourth of MOP at the time of flowering initiation followed by last top dressing comprising rest of urea and MOP at the time of fruit initiation. The whole field was divided into three blocks having l m space between the block and each block was again sub-divided into 7 plots (3m x 2m) with 1 m space between the plots, eight pits were made in each plot at a distance of 1m between rows and 0.75 m between pits on a row.

3.6. Raising of Seedlings and Transplanting

Brinjal seeds (variety: Singnath) were collected from the Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. A seedbed measuring 5m x l m was prepared and seeds were sown on 2nd October, 2009. Thirty five days-old healthy seedlings were transplanted on 15 November, 2009 in the main field. A total of 168 seedlings were transplanted in 21 plots at the rate of 08 seedlings per plot.

3.7. Cultural Operations

The pits which have transplanted seedlings were irrigated lightly and replanting was done with healthy ones in place of' any damaged seedlings. Supplementary irrigation was applied at an interval of 2-3 days. Weeding in the plots was done as and whenever necessary. The MOP and Urea fertilizers were top dressed in 3 splits as described earlier.

3.8. Details of Treatments

Six treatments including a untreated control were considered under this investigation which are as follows:

T_1= Application of Mehogoni oil @ 5ml/L of water at 28 days after transplanting and repeated at 7days interval.

T_2 = Application of Mehogoni oil @ 3ml/L of water at 28 days after transplanting and repeated at 7days interval.

T_3 = Application of Neem oil @ 5ml/L of water at 28 days after transplanting and repeated at 7days interval.

T_4 = Application of Neem oil @ 3ml/L of water at 28 days after transplanting and repeated at 7days interval.

T_5 = Application of Marshal 20 EC @ 2ml/L of water at 28 days after transplanting and repeated at 7days interval.

T_6 = Application of Ripcord 10 EC @ 1ml/L of water at 28 days after transplanting and repeated at 7days interval.

T_7= Untreated control

3.9. Insecticides Application

Neem oil, Mehogony oil, Ripcord 10EC and Marshal 20 EC were sprayed in assigned plots with recommended dosages by a Knapsack sprayer. The spraying was always done in the afternoon to avoid bright sunlight and drift caused by strong wind and adverse effect of pollinating bees. The spray materials were applied uniformly to obtain complete coverage of whole plants of the assigned plots. Caution was taken to avoid any drift of the spray mixture to the adjacent plots at the time of the spray application. At each spray application the spray mixture was freshly prepared.

3.10. Monitoring of infestation

For the purpose of determining the incidence of adults and the level of infestation during insecticide application, a close monitoring of egg deposition until the eggs were first observed and of shoot infestation up to fruit set, and fruit infestation up to final harvest has been carried out at every alternate days from 8 plants per plot. The infestation data collected have been transformed into percent each time so that the application of insecticide can be made whenever it reaches the pre-set level.

Figure 2. Infested shoots of brinjal due to brinjal shoot and fruit borer

Figure 3. Infested fruit before

Figure 4. Healthy fruit before

Figure 5. Infested fruit after

Figure 6. Healthy fruit after harvest

Figure 7. A full grown larva inside the shoot

Figure 8. A full grown larva feeding inside the fruit

Figure 9. Pupa of brinjal shoot and fruit borer

Figure 10. Adult of brinjal shoot and fruit borer

3.11. Data Recording

The following parameters were considered for evaluating the effectiveness of each treatment in controlling the brinjal shoot and fruit borer infestation:

3.11.1. Shoot Infestation

The total number of shoots and the number of infested shoots were recorded from 2 tagged plants from each plot at 7 days intervals during the period from 15 December, 2009 to 15 April, 2010. Shoot infestation was calculated in percent using the following formula:

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

3.11.2. Fruit infestation and Yield

At each harvest, data on the number of healthy and infested fruit and their weight separately per plot per treatment were recorded from 2 tagged plants at 7 days intervals. Twelve harvests were done throughout fruiting season. Fruits were harvested at 7 days interval. Fruit infestation was calculated using the following formula:

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

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

For obtaining healthy fruit yield and infested fruit yield, the weights of healthy fruit and infested fruits per 2 tagged plants per plot of 12 harvests have been summed up and then transformed into per plot healthy fruit yield and infested fruit yield simply by calculating the same for 42 tagged plants. The plot yield of healthy and infested fruit thus obtained has been then transformed into healthy fruit yield and infested fruit yield in ton per hectare. Sum of the healthy fruit yield and infested fruit yield is finally expressed as the total yield in ton per hectare.

3.11.3. Infestation Intensity per Fruit

The infestation intensity expressed in terms of number of bores per fruit has also been considered as one of the parameters for differentiating the effectiveness of the treatments. The reason behind this is that although even a single number of bore in the fruit designates it as infested fruit, the extent of damage and market price are likely to vary depending on the number of bore per fruit i. e., infestation intensity per fruit. For convenience of expression of infestation intensity per fruit, four scales corresponding to the number of bores per fruit have been used as follows.

Scale 1 (Low intensity) : 1-2 bores per fruit

Scale 2 (Moderate intensity) : 3-4 bores per fruit

Scale 3 (High intensity) : 5-6 bores per fruit

Scale 4 (Very high intensity): > 7 bores per fruit.

Such type of scale also reported by Rahman (1999). The infested fruits of total 42 tagged plants at each harvest were counted treatment wise separately and then sorted out into 4 scales based on the number of bores per fruit as above. The total number of infested fruit was obtained by summing up those of the 12 harvests altogether while the total number of infested fruits belonging to each of the above 4 scales was obtained by summing up those of 12 harvests scale wise. Then the percent of each of above 4 scales was calculated using the following formula:

Number of infested fruits belonging to scale i

$$\% \text{ of scale} = \frac{\qquad\qquad}{\text{Total number of infested fruits}} \times 100$$

Where i = ranged from scale 1 to scale 4.

3.11.4. Extent of Damage

In order to see the impact of infestation intensity on the extent of damage per fruit, 5 fruit belonging to each of the above 4 scales at harvest were randomly selected and the following data were recorded.

Fruit length: Length of the individual fruit was measured in cm and then the average of the samples was calculated.

Girth of fruit: Girth of individual fruit was measured in cm and then the average of the samples was calculated.

Fruit weight: Weight of the individual fruit was measured in gm and then the average of the samples was calculated

Damage length: For measuring the damage length, sample fruit belonging to each scale were cut open and the length of the damage indicated by brown- rot flesh per fruit was measured on cm from which average damage length was calculated.

Damage weight: For measuring the damage weight, the damaged portion of the cut sample fruit belonging to each scale were cut separated and weighed in gm from which the average damage weight was calculated.

Fresh weight: For measuring the fresh weight the portion except the damaged portion of the sample fruits were weighed in gm from which the average fresh weight was calculated.

3.12. Photographs Preparation

Several photographs were taken pertaining to the experiment field, nature of damage and life stages of the brinjal shoot and fruit borer.

3.13. Benefit/ Cost Analysis

For benefit cost analysis record of costs incurred in each treatment and that of control we maintained, similarly, the price of the harvested fruits of each treatment and that of control were calculated at market rate. Benefit-Cost analysis was expressed in terms of Benefit-Cost ratio (BCR).

3.14. Data Analysis

All the data collected and processed as stated above were analyzed statistically alter necessary appropriate transformations. The analysis of variance (ANOVA) of different parameters was done and the means were tested for significant difference using the Duncan's Multiple Range Test (DMRT).

CHAPTER IV

RESULTS AND DISCUSSION

The comparative effectiveness of some selected botanicals and chemical insecticides used at recommended doses for the management of brinjal shoot and fruit borer has been presented in the following sections.

4.1. Effect of Different Treatments on Shoots Infestation

As shown in Table 1, the shoot infestation was the lowest (3.82%) in the plots treated with Marshal 20EC at 28 days after transplanting and repeated 7 days interval (T_5). The second lowest shoot infestation (4.35%) was observed in the plots treated with Ripcord 10 EC at 28 days after transplanting and repeated 7 days interval (T_6) which was very close to T_5 (3.82%). The highest 16.25% shoot infestation was observed in control treatment which was close to the treatment 15.57% having Mehogoni oil @ 3ml/L of water (T_2).

Thus it is seen from the same Table 1 that Marshal 20EC (T_5) gave the significantly highest reduction in shoot infestation (72.18%) over control. This was followed by a 68.84%, 20.51%, 11.92%, 7.15, and 2.54% reduction in shoot infestation over control achieved by Ripcord 10 EC @ 1ml/L of water (T_6), Neem oil @ 5ml/L of water (T_3), Neem oil @ 3ml/L of water (T_4), Mehogoni oil @ 5mml/L of water (T_1) and Mehogoni oil @ 3ml/L of water (T_2), applied at 28 days after transplanting and repeated 7 days interval respectively.

Rahman *et al.*, (2009) and Kabir *et al.* (1994) observed similar results where the chemical insecticide was not very effective against brinjal shoot and fruit borer. Rahman *et al.*, (2009) reported that Marshal 20 EC @ 1.5 ml per litre of water performed the best ensuring the lowest shoot (7.59%) infestation.

Table 1. Effect of different treatments on shoot infestation against brinjal shoot and fruit borer.

Treatment	% shoot infestation of brinjal	% reduction of shoot infestation over control
T_1	14.38 b	07.15
T_2	15.57 ab	02.54
T_3	11.75 d	20.51
T_4	13.39 c	11.92
T_5	3.82 f	72.18
T_6	4.35 ef	68.84
T_7	16.25 a	--
$LSD_{(0.05)}$	1.042	--
CV (%)	4.58	--

N.B. The same letter (s) in the column means the results are statistically similar.

T_1 = Application of Mehogoni oil @ 5ml/L of water at 28 days after transplanting and repeated at 7days interval

T_2 = Application of Mehogoni oil @ 3ml/L of water at 28 days after transplanting and repeated at 7days interval

T_3 = Application of Neem oil @ 5ml/L of water at 28 days after transplanting and repeated at 7days interval

T_4 = Application of Neem oil @ 3ml/L of water at 28 days after transplanting and repeated at 7days interval

T_5 = Application of Marshal 20 EC @ 2ml/L of water at 28 days after transplanting and repeated at 7days interval

T_6 = Application of Ripcord 10 EC @ 1ml/L of water at 28 days after transplanting and repeated at 7days interval

T_7 = Untreated control

4.2. Effect of Different Treatments on Fruit Infestation

The comparative effectiveness of various treatments on fruit infestation by the brinjal shoot and fruit borer has been evaluated in terms of percent (%) fruit infestation by number and weight as well as in percent (%) reduction in infestation over control is presented in Table 2.

The result showed that the lowest fruit infestation of 12.29% by number and 8.73% by weight was observed in T_5 (Marshal 20 EC @ 2ml/L of water at 28 days after transplanting and repeated at 7days interval) where the highest percent (%) reduction over control by number and weight were 62.02% and 72.12% respectively from the same treatment. The second lowest percent (%) fruit infestation by number and weight were 17.36% and 10.57% respectively from T_6 (Ripcord 10 EC @ 1ml/L of water at 28 days after transplanting and repeated at 7days interval) where percent (%) reduction over control were 51.05% and 68.61% respectively with the same treatment.

All these treatments differed most significantly from untreated control treatment, T_7 that recorded the highest fruit infestation (47.58% by number and 48.42% by weight). The rest of the treatments; T_1 (Mehogoni oil @ 5ml/L of water), T_2 (Mehogoni oil @ 3ml/L of water), T_3 (Neem oil @ 5ml/L of water), and T_4 (Neem oil @ 3ml/L of water) had the intermediate level of infestation by number (29.56%, 32.90%, 21.13%, and 24.05% respectively) and by weight (23.38%, 26.51%, 12.22%, and 14.37% respectively) differing significantly from each other. In terms of percent reduction of fruit infestation over control from another treatments, T_1 (26.76% by number and 41.07% by weight), T_2 (21.35% by number and 36.39% by weight), T_3 (43.45% by number and 66.78% by weight), and T_4 (37.76% by number and 62.27% by weight) also showed good performance. It is mentioned that under treated treatments, T_2 (Mehogoni oil @ 3ml/L of water) showed the lowest reduction over control by number by number (21.35%) and by weight (36.39%).

The results thus obtained by Rahman *et al.,* (2009) reported that Marshal 20 EC @ 1.5 ml per litre of water (T_8) performed the best ensuring the lowest fruit infestation (4.16%) rendering 88.06% and 88.99% reduction in fruit by number and by weight respectively. Kabir *et al.* (1994) reported similar results to the present study and apprehended development of resistance as a cause of poor performance of insecticides in reducing the brinjal shoot and fruit borer infestation. Prakash (1988) also reported that insecticides were notable to suppress this borer pest below the Economic Injury Level (EIL).

Thus it is revealed from Table 1 and 2 that the rate of infestation is higher in fruits than the shoots which are in consistence with the findings reported by Maleque (1998) who also observed that the caterpillars preferred the fruits to shoots during the fruiting stage.

Table 2. Effect of different treatments on fruit infestation of brinjal.
N.B. The same letter (s) in the column means the results are statistically similar.

Treatment	% fruit infestation (by number)	% reduction over control (by number)	% fruit infestation (by weight)	% reduction over control (by weight)
T_1	29.56 c	26.76	23.38 c	41.07
T_2	32.90 b	21.35	26.51 b	36.39
T_3	21.13 e	43.45	12.22 e	66.78
T_4	24.05 d	37.76	14.37 d	62.27
T_5	12.29 g	62.02	08.73 g	72.12
T_6	17.36 f	51.05	10.57 f	68.61
T_7	47.58 a	--	49.42 a	--
$LSD_{(0.05)}$	2.349	--	1.754	--
CV (%)	6.26	--	5.68	--

T_1 = Application of Mehogoni oil @ 5ml/L of water at 28 days after transplanting and repeated at 7days interval
T_2 = Application of Mehogoni oil @ 3ml/L of water at 28 days after transplanting and repeated at 7days interval
T_3 = Application of Neem oil @ 5ml/L of water at 28 days after transplanting and repeated at 7days interval
T_4 = Application of Neem oil @ 3ml/L of water at 28 days after transplanting and repeated at 7days interval
T_5 = Application of Marshal 20 EC @ 2ml/L of water at 28 days after transplanting and repeated at 7days interval
T_6 = Application of Ripcord 10 EC @ 1ml/L of water at 28 days after transplanting and repeated at 7days interval
T_7 = Untreated control

4.3 Effect of different Treatments on the Yield of Brinjal

Effect of different treatments on yield has been evaluated in terms of total fruit yield, healthy fruit yield and infested fruit yield obtained in each treatment during the entire period of the crop. In Table 3 percent (%) reduction over control also included for each of the yield component.

The results obtained from the present experiment represented in Table3 shows that the maximum total fruit yield was (31.89 t/ha) with the application of Marshal 20 EC @ 2ml/L of water at 28 days after transplanting and repeated at 7days interval followed by significantly lower yield (29.65 t/ha) by T_6 (Ripcord 10 EC @ 1ml/L of water at 28 days after transplanting and repeated at 7days interval) and then gradually decreased yield; 27.14 t/ha, 26.22 t/ha, 25.16 t/ha and 23.95 t/ha were achieved from T_3 (Neem oil @ 5ml/L of water), T_4 (Neem oil @ 3ml/L of water), T_1 (Mehogoni oil @ 5ml/L of water) and T_2 (Mehogoni oil @ 3ml/L of water) respectively where the lowest yield (20.18 t/ha) was obtained from T_7 (Untreated control treatment). It was also observed that under different methods of application of different insecticide within different treatment, T_2 (Mehogoni oil @ 3ml/L of water) showed the lowest total brinjal yield (23.95 t/ha). In case of infested fruit yield/ha, the lowest (2.78 t/ha) was achieved from T_5 (Marshal 20 EC @ 2ml/L of water) and gradually increased infested fruit yield was observed from T_6 (3.14t/ha), T_3 (3.32 t/ha), T_4 (3.76 t/ha), T_1 (5.88 t/ha), and T_2 (6.35 t/ha).

Thus it is observed that application of Mehogoni oil @ 3ml/L of water and @ 5 ml/L of water was not good enough to protect the fruit yield from the pest attack. Results showed that the yield of infested fruit was maximum (6.35 t/ha and 5.88 t/ha) in T_2 (Mehogoni oil @ 3ml/L of water) and T_1 (Mehogoni oil @ 5ml/L of water) respectively and the lowest was recorded from T_5 (Marshal 20 EC @ 2ml/L of water) within the treated plots where T_7 (Untreated control) showed the highest infested fruit (9.98 t/ha). Accordingly, the yield of healthy fruit/ha was the highest (29.11 t/ha) in T_5 (Marshal 20 EC @ 2ml/L of water) while the lowest (17.60 t/ha) within treated plots was in T_2 (Mehogoni oil @ 3ml/L of water) and T_1 (Mehogoni oil @ 5ml/L of water) also showed lower healthy fruit yield (19.28 t/ha) compared to others. The other treatments; T_3 (23.82 t/ha), T_4 (22.46 t/ha) and T_6 (29.11 t/ha) showed intermediate level of healthy fruit yield/ha. Untreated control treatment showed the lowest healthy fruit yield (10.20 t/ha).

A further analysis of the yield data to assess the impact of each treatment on yield over control as shown in Table 3 suggests that T_5 ensured maximum increase (185.39%) of healthy fruit yield followed by gradually less increase in T_6 (159.90%), T_3 (133.53%), T_4 (120.20%), T_1 (89.02%) and in T_2 (72.55%). Conversely, maximum reduction (72.14%) in infested fruit yield over control was observed in T_5 while it was lower in T_6 (68.54%) followed by T_3 (66.73%), T_4 (62.32%), T_1 (41.08%) and T_2 (36.37%). Accordingly, as a cumulative impact, maximum increase in total fruit yield over control was observed in T_5 (58.03%) followed by 46.93% in T_6, 34.49% in T_3, 29.93% in T_4, 24.68% in T_1 and 18.68% in T_2.

Table 3. Effect of different treatments on the yield and increase/decrease in yield over control of brinjal.

Treatment	Yield and increase/decrease in yield					
	Healthy yield by weight (t/ha)	**Increase (+)/decrease (-) over control (%)**	**Infested Yield by weight (t/ha)**	**Increase (+)/decrease (-) over control (%)**	**Total Yield by weight (t/ha)**	**Increase (+)/decrease (-) over control (%)**
T_1	19.28 e	089.02	5.88 c	-41.08	25.16 e	24.68
T_2	17.60 f	072.55	6.35 b	-36.37	23.95 f	18.68
T_3	23.82 c	133.53	3.32 e	-66.73	27.14 c	34.49
T_4	22.46 d	120.20	3.76 d	-62.32	26.22 d	29.93
T_5	29.11 a	185.39	2.78 g	-72.14	31.89 a	58.03
T_6	26.51 b	159.90	3.14 ef	-68.54	29.65 b	46.93
T_7	10.20 g	--	9.98 a	--	20.18	--
$LSD_{(0.05)}$	1.149	--	0.246	--	1.425	--
CV (%)	4.58	--	6.79	--	7.14	--

N.B. The same letter (s) in the column means the results are statistically similar.

T_1 = Application of Mehogoni oil @ 5ml/L of water at 28 days after transplanting and repeated at 7days interval

T_2 = Application of Mehogoni oil @ 3ml/L of water at 28 days after transplanting and repeated at 7days interval

T_3 = Application of Neem oil @ 5ml/L of water at 28 days after transplanting and repeated at 7days interval

T_4 = Application of Neem oil @ 3ml/L of water at 28 days after transplanting and repeated at 7days interval

T_5 = Application of Marshal 20 EC @ 2ml/L of water at 28 days after transplanting and repeated at 7days interval

T_6 = Application of Ripcord 10 EC @ 1ml/L of water at 28 days after transplanting and repeated at 7days interval

T_7 = Untreated control

Although direct comparison of the present findings could not be done with the findings of elsewhere due to lack of reference of similar treatments, however, several workers have reported similar impact of Abamectin 100WSC, Nimbicidin, Suntap50 SP, Marshal 20 EC and Ripcord 10 EC. The efficacy of 5 selected insecticides, two resistant lines and female sex pheromone was conducted by Rahman *et al.,* (2009) against Brinjal shoot and fruit borer (BSFB) (*Leucinodes orbonalis* Guenee). However, the effectiveness of the options in reducing the shoot and fruit infestation differed significantly with different treatments over the control. Marshal 20 EC @ 1.5 ml per litre of water (T_8) performed the best ensuring the lowest shoot and fruit infestation (7.59% and 4.16% respectively) rendering 78.37% reduction in shoot and 88.06% and 88.99% reduction in fruit by number and by weight respectively, which was followed by Suntap 50 SP @ 5 mg per litre of water that kept shoot and fruit infestation level at 10.77% and 11.53%, respectively. The Marshal 20 EC @ also performed the best ensuring the highest healthy fruit yield (25.19 t /ha) as against only 2.09 t /ha infested fruit yield as compared to untreated control, which provided only 12.41 t /ha healthy fruit yield as against 9.91 t /ha infested fruit yield. The results thus indicated that in all aspects Marshal 20 EC (Carbosulfan) and Suntap 50 SP were most effective among insecticides followed by sex pheromone and other options.

4.4. Effect on Infestation Intensity per Fruit

The effects of different treatments on the infestation intensity per fruit expressed in terms of percent fruits having infestation intensity corresponding to any of 4 scales such as Scale 1 (low infestation intensity; 1-2 bores/fruit), Scale 2 (moderate infestation intensity; 3-4 bores/fruit), Scale 3 (high infestation intensity; 5-6 bores/fruit) and Scale 4 (very high infestation intensity; ≥7 bores/fruit) are presented in Table 4. It is seen from the Table 4 that among the infested fruits those belonging to Scale 4 was only 8.25% in T_6 having no significant difference with T_3 (9.42%) and T_4 (9.82%), as against 19.66% in control where T_1 (10.34%) and T_2 (12.02%) were significantly different from all other treatment but T_5 had no infested fruit. While those belonging to Scale 3 was 14.86% in T_1 and 14.19% in T_3, 14.51% in T_4, 14.03% in T_5 and 14.61% in T_6 having no significant difference among them where T_2 (15.87%) and control treatment (20.87%) had significant difference between them and was also significantly different from all other treatments.

The infested fruits belonging to Scale 2 followed considerably higher value in all the cases such as 30.42% in T_4 having no significant difference with T_6 (30.49%) where T_5 (36.34%), T_3 (31.15%), T_1 (28.15%), T_2 (27.75%) and Control treatment (22.66%) having significant difference. The similar trend was also observed in scale 1. The most significant finding is that considerably a very high proportion of infested fruits (49.63%) belonged to Scale 1 in T_5 having significant difference with 36.80% in control. On the other hand T_1 (46.65%), T_2 (44.37%), T_3 (45.24%), T_4 (45.25%) and T_6 (46.65) having significantly higher bores (1-2 bores) per fruit over control (36.80%).

Thus it may be inferred from the above analysis that the proportion of infested fruits in the infested category under different treatments would vary greatly in terms of infestation intensity i.e., in terms of number of bores per fruit. So, although an insecticide treatment might be effective in protecting the crop significantly against infestation in terms of reducing the number of bores per fruit, its effect would not be reflected exactly if the fruits are considered infested irrespective of the number of bores per fruit. For example, referring back to the effects of the treatments on fruit infestation as shown in Table 2, in T_5, 12.29% fruits were found infested of which a very big proportion i.e., 49.63% belonged to Scale 1 (only 1-2 bores/fruit) while a very small proportion, i.e., only 14.03% belonged to Scale 3 (5-6 bores per fruit) and there was no infested fruit belonged to Scale 4 (>7 bores per fruit) as against 47.58% infested fruits in control of which a small proportion i.e., only 36.80% belonged to Scale 1 (1-2 bores per fruit) while a large proportion i.e., 20.87% belonged to Scale 3 (5-6 bores per fruit) and 19.66% belonged to Scale 4 (>7 bores per fruit). The results obtained in the present study were similar with that of the Kabir *et al.,* (2003) and was also supported by Rahman *et al.,* (2009).

Table 4. Effect of different treatments on infestation intensity and grading of fruits infested by Brinjal shoot and fruit borer.

Treatments	**Percent (%) of infested fruits belonging to different scales**			
	Scale 1	Scale 2	Scale 3	Scale 4
T_1	46.65 b	28.15 d	14.86 c	10.34 c

T_2	44.37 d	27.75 e	15.87 b	12.02 b
T_3	45.24 c	31.15 b	14.19 c	09.42 d
T_4	45.25 c	30.42 c	14.51 c	09.82 d
T_5	49.63 a	36.34 a	14.03 c	00.00 e
T_6	46.65 b	30.49 c	14.61 c	08.25 d
T_7	36.80 e	22.66 f	20.87 a	19.66 a
$LSD_{(0.05)}$	1.742	0.416	1.148	1.568
CV (%)	8.26	6.24	7.33	5.22

N.B. The same letter (s) in the column means the results are statistically similar.

T_1 = Application of Mehogoni oil @ 5ml/L of water at 28 days after transplanting and repeated at 7days interval

T_2 = Application of Mehogoni oil @ 3ml/L of water at 28 days after transplanting and repeated at 7days interval

T_3 = Application of Neem oil @ 5ml/L of water at 28 days after transplanting and repeated at 7days interval

T_4 = Application of Neem oil @ 3ml/L of water at 28 days after transplanting and repeated at 7days interval

T_5 = Application of Marshal 20 EC @ 2ml/L of water at 28 days after transplanting and repeated at 7days interval

T_6 = Application of Ripcord 10 EC @ 1ml/L of water at 28 days after transplanting and repeated at 7days interval

T_7 = Untreated control

4.5 Effect of different treatments on yield contributing parameters

4.5.1 Fruit length

Length of fruit was significantly influenced by different treatments (Table 5). Results indicated that the highest fruit length (28.03cm) was achieved from T_5 (Marshal 20 EC @ 2ml/L of water) which was not significantly different from T_6 (Ripcord 10 EC @ 1ml/L of water) (27.62 cm) where the lowest (23.64 cm) was obtained from control treatment. The results obtained from another treatments were 25.92, 25.48, 26.88 and 26.42 cm from T_1 (Mehogoni oil @ 5ml/L of water), T_2 (Mehogoni oil @ 3ml/L of water), T_3 (Neem oil @ 5ml/L of water) and T_4 (Neem oil @ 3ml/L of water) respectively. But among the treated plots, T_2 (Mehogoni oil @ 3ml/L of water) showed the lowest fruit length (25.48 cm).

In terms of percent (%) reduction over control, the highest reduction (18.57%) over control was observed from T_5 (Marshal 20 EC @ 2ml/L of water) followed by T_6 (16.83%), T_3 (13.71%), T_4 (11.76%) and T_1 (9.64%) where the lowest (7.78%) was observed from T_2 (Mehogoni oil @ 3ml/L of water).

4.5.2 Girth of fruit

Girth of fruit was also significantly influenced by different treatments (Table 5). Results indicated that the highest girth of fruit (12.82cm) was achieved from T_5 (Marshal 20 EC @ 2ml/L of water) which was significantly different from all other treatments followed by T_6 (11.98 cm), T_3 (11.72 cm), T_4 (11.34 cm), T_1 (11.14 cm) and T_2 (11.02 cm). On the other hand the lowest girth of fruit (10.04) was obtained by untreated control. But in terms of treated plots, the lowest (11.02 cm) was gained from T_2 (Mehogoni oil @ 3ml/L of water) which was significantly same with T_1 (Mehogoni oil @ 5ml/L of water).

In terms of percent (%) reduction over control, the highest reduction (27.69%) over control was observed from T_5 (Marshal 20 EC @ 2ml/L of water) followed by T_6 (19.32%), T_3 (16.73%), T_4 (12.95%) and T_1 (10.96%) where the lowest (9.76%) was observed from T_2 (Mehogoni oil @ 3ml/L of water).

4.5.3 Weight of edible portion of infested fruit

Significant variation was also observed for edible portion of infested fruit (Tale 5). It was mentioned that the highest weight of edible portion per infested fruit

(152.36 g) was achieved from T_5 (Marshal 20 EC @ 2ml/L of water) which was significantly different from all other treatments followed by T_6 (136.32 g), T_3 (120.24 g), T_4 (108.23 g), T_1 (098.44 g) and T_2 (82.16 g). On the other hand the lowest weight of edible portion per infested fruit (66.34 g) was obtained by untreated control. But in terms of treated plots, the lowest (82.16 g) was gained from T_2 (Mehogoni oil @ 3ml/L of water).

In terms of percent (%) reduction over control, the highest reduction (129.67%) over control was observed from T_5 (Marshal 20 EC @ 2ml/L of water) followed by T_6 (105.49%), T_3 (81.25%), T_4 (63.14%) and T_1 (48.39%) where the lowest (23.85%) was observed from T_2 (Mehogoni oil @ 3ml/L of water).

Table 5. Effect of different treatments on yield contributing parameters infested by Brinjal shoot and fruit borer

Treatment	Length/fruit (cm)	% reduction over control	Girth/fruit (cm)	% reduction over control	Edible portion/infested fruit (g)	% reduction over control
T_1	25.92 d	09.64	11.14 d	10.96	098.44 e	048.39
T_2	25.48 e	07.78	11.02 d	09.76	082.16 f	023.85
T_3	26.88 bc	13.71	11.72 bc	16.73	120.24 c	081.25
T_4	26.42 b	11.76	11.34 c	12.95	108.23 d	063.14
T_5	28.03 a	18.57	12.82 a	27.69	152.36 a	129.67
T_6	27.62 a	16.83	11.98 b	19.32	136.32 b	105.49

T_7	23.64 f	--	10.04 e	--	066.34 g	--
$LSD_{(0.05)}$	0.446	--	0.524	--	4.569	--
CV (%)	8.94	--	6.25	--	6.86	--

N.B. The same letter (s) in the column means the results are statistically similar.

T_1 = Application of Mehogoni oil @ 5ml/L of water at 28 days after transplanting and repeated at 7days interval

T_2 = Application of Mehogoni oil @ 3ml/L of water at 28 days after transplanting and repeated at 7days interval

T_3 = Application of Neem oil @ 5ml/L of water at 28 days after transplanting and repeated at 7days interval

T_4 = Application of Neem oil @ 3ml/L of water at 28 days after transplanting and repeated at 7days interval

T_5 = Application of Marshal 20 EC @ 2ml/L of water at 28 days after transplanting and repeated at 7days interval

T_6 = Application of Ripcord 10 EC @ 1ml/L of water at 28 days after transplanting and repeated at 7days interval

T_7 = Untreated control

4.6. Benefit / Cost Analysis

Benefit/cost ratio (BCR) of various controlling methods for the control of brinjal shoot and fruit borer are presented in Table 6. In this study untreated control (T_7) did not required any pest management cost. It is to be noted here that the expenses incurred referred to those only on pest control. Thus it is revealed from Table 6 that the adjusted net return was the highest (Tk. 402540.00) in T_5 (Marshal 20 EC @ 2ml/L of water) followed by Tk. 333180.00 in T_6 (Ripcord 10 EC @ 1ml/L of water), Tk. 258240.00 in T_3 (Neem oil @ 5ml/L of water), 226320.00 in T_4 (Neem oil @ 3ml/L of water), 170700.00 in T_1 (Mehogoni oil @ 5ml/L of water) and Tk. 129900.00 in T_2 (Mehogoni oil @ 3ml/L of water).

Similarly, it is revealed that the BCR was the highest (11.45) in case of T_5 which was higher than all other treatments having BCR from T_6 (10.10), T_3 (8.47), T_4 (7.67), T_1 (6.19) and T_2 (4.85).

However, much higher BCR had been reported from an experiment conducted at the Entomology Division, BARI during Rabi 1993-94 (Anonymous, 1994). As per the report, the BCR at any one of 5 arbitrary ETLs such as 1,3,5,7 and 10% and even the schedule spray that required 7 sprayings, was economic. The minimum number of sprays (2 only) and the lowest cost of brinjal shoot and fruit borer control accrued at 10% ETI, which had the highest BCR (Tk 11.27 benefit per one Taka cost). However, these findings are not adequate to draw a conclusion on the ETL based on BCR.

Table 6. Economic analysis of different treatments for the control of brinjal shoot and fruit borer

Treatments	Cost of pest Management (Tk.)	Yield (t/ha)		Gross return (Tk.)	Net Return (Tk.)	Adjusted net return (Tk.)	Benefit cost ratio
		Healthy	Infested				
Mehogoni oil @ 5ml/L of water	27900	19.28	5.88	684240	656340	170700	6.19
Mehogoni oil @ 3ml/L of water	26760	17.6	6.35	642300	615540	129900	4.85
Neem oil @ 5ml/L of water	30480	23.82	3.32	774360	743880	258240	8.47
Neem oil @ 3ml/L of water	29520	22.46	3.76	741480	711960	226320	7.67
Marshal 20 EC @ 2ml/L of water	35160	29.11	2.78	923340	888180	402540	11.45
Ripcord 10 EC @ 1ml/L of water	33000	26.51	3.14	851820	818820	333180	10.10
Untreated control	0	10.20	9.98	485640	485640	--	--

Cost of treatment management including labour cost		Total
Mehogoni oil @ 5ml/L of water @ Tk. 2325/ha for single spray (12 spray)	=	27900
Mehogoni oil @ 3ml/L of water @ Tk. 2230/ha for single spray (12 spray)	=	26760
Neem oil @ 5ml/L of water @ Tk. 2540/ha for single spray (12 spray)	=	30480
Neem oil @ 3ml/L of water @ Tk. 2460/ha for single spray (12 spray)	=	29520
Marshal 20 EC @ 2ml/L of water @ Tk. 2930/ha for single spray (12 spray)	=	35160
Ripcord 10 EC @ 1ml/L of water @ Tk. 2750/ha for single spray (12 spray)	=	33000
Untreated control	=	0

Market price of brinjal: Tk 30.00 for healthy and Tk. 18.00 for infested fruit

CHAPTER V

SUMMARY AND CONCLUSION

An experiment was conducted at the experimental field of Sher-e-Bangla Agricultural University (SAU), Sher-e Bangla Nagar, Dhaka, to evaluate some selected botanicals and chemical insecticides for the management of brinjal shoot and fruit borer (BSFB)**'**, during October, 2009 to April, 2010

The experiment comprised seven (7) treatments viz. (i) T_1 = Application of Mehogoni oil @ 5ml/L of water at 28 days after transplanting and repeated at 7days interval, (ii) T_2 = Application of Mehogoni oil @ 3ml/L of water at 28 days after transplanting and repeated at 7days interval, (iii) T_3 = Application of Neem oil @ 5ml/L of water at 28 days after transplanting and repeated at 7days interval, (iv) T_4 = Application of Neem oil @ 3ml/L of water at 28 days after transplanting and repeated at 7days interval, (v) T_5 = Application of Marshal 20 EC @ 2ml/L of water at 28 days after transplanting and repeated at 7days interval, (vi) T_6 = Application of Ripcord 10 EC @ 1ml/L of water at 28 days after transplanting and repeated at 7days interval and (vii) T_7 = Untreated control.

The experiment was set up in Randomized Complete Block Design (factorial) with three replications. The experimental plot was fertilized with recommended doses of brinjal. Data on different growth and yield parameters were recorded and analyzed statistically.

Data recorded on shoot infestation, the lowest (3.82%) was with Marshal 20EC @ 2ml/L of water at 28 days after transplanting and repeated 7 days interval (T_5). On the other hand, the highest shoot infestation of 16.25% was observed in control treatment which was close to the treatment having Mehogoni oil @ 3ml/L of water (T_2) that was 15.57% shoot infestation. Thus it is seen that Marshal 20EC @ 2ml/L of water (T_5) gave the significantly highest reduction in shoot infestation (72.18%) over control which was close to T_6 (Ripcord 10 EC @ 1ml/L of water) (68.84%) where the lowest (2.54%) was with T_2 (Mehogoni oil @ 3ml/L of water).

The different insecticide was applied at 28 days after transplanting and repeated at 7days interval.

In terms of percent (%) fruit infestation by number and weight as well as in percent (%) reduction over control gave significant results regarding different insecticide application. The lowest fruit infestation of 12.29% by number and 8.73% by weight was observed in T_5 (Marshal 20 EC @ 2ml/L of water) where the highest percent (%) reduction over control by number and weight were 62.02% and 72.12% respectively from the same treatment. On the other hand, the highest fruit infestation (47.58% by number and 48.42% by weight) was recorded with control treatment. But with the treated plot, T_2 (Mehogoni oil @ 3ml/L of water) showed the highest infestation by number (32.90%) and by weight (26.51%) where the lowest percent reduction over control (21.35% by number and 36.39% by weight) was with the same treatment.

Effect of different treatments on yield (total fruit yield, healthy fruit yield and infested fruit yield) has been evaluated with percent (%) reduction over control. The maximum total fruit yield was (31.89 t/ha) with the application of Marshal 20 EC @ 2ml/L of water where percent (%) increase of total yield over control was also highest (58.03%) with the same treatment. The lowest total yield (20.18 t/ha) was obtained from T_7 (Untreated control treatment). But under different methods of application of different insecticide within different treatment, T_2 (Mehogoni oil @ 3ml/L of water) showed the lowest total brinjal yield (23.95 t/ha) where percent (%) increase of total yield over control was also lowest (18.68%) with the same treatment.

In case of infested fruit yield/ha, the lowest (2.78 t/ha) was achieved from T_5 (Marshal 20 EC @ 2ml/L of water) where the highest infested fruit yield (9.98 t/ha). Results also revealed that the yield of infested fruit was maximum (6.35 t/ha) in T_2 (Mehogoni oil @ 3ml/L of water) within the treated plots.

Maximum reduction (72.14%) in infested fruit yield over control was observed in T_5 (Marshal 20 EC @ 2ml/L of water) while it was lowest (36.37%) in T_2 (Mehogoni oil @ 3ml/L of water).

Accordingly, the yield of healthy fruit/ha was the highest (29.11 t/ha) in T_5 (Marshal 20 EC @ 2ml/L of water) where untreated control treatment showed the lowest healthy fruit yield (10.20 t/ha) while within treated plots, the lowest (17.60 t/ha) was with T_2 (Mehogoni oil @ 3ml/L of water). Marshal 20 EC @ 2ml/L of water (T_5) ensured maximum increase (185.39%) of healthy fruit yield over control where the lowest (72.55%) was observed in T_2 (Mehogoni oil @ 3ml/L of water).

The effects of different treatments on the infestation intensity per fruit as observed that among the infested fruits those belonging to Scale 4 were not found in T_5 (Marshal 20 EC @ 2ml/L of water) followed by 8.25% to 12.02% from another treatments as against 19.66% in control. The most significant finding is that considerably a very high proportion of infested fruits (49.63%) belonged to Scale 1 in T_5 (Marshal 20 EC @ 2ml/L of water) followed by 46.65% in T_1, 44.37% in T_2, 45.24% in T_3, 45.25% in T_4 and 46.65% in T_6 against only 36.80% in control.

Yield contributing parameters were also significantly influenced by different treatments. Results indicated that the highest fruit length (28.03cm), girth of fruit (12.82cm) and weight of edible portion per infested fruit (152.36 g) were achieved from T_5 (Marshal 20 EC @ 2ml/L of water) where highest percent (%) reduction over control (18.57%, 27.69% and 129.67% respectively) were with the same treatment. On the other hand the lowest length of fruit (23.64 cm), girth of fruit (10.04 cm) and weight of edible portion per infested fruit (66.34 g) were obtained by untreated control. But among the treated plots, T_2 (Mehogoni oil @ 3ml/L of water) showed the lowest fruit length (25.48 cm), girth of fruit (11.02 cm) and weight of edible portion per infested fruit (82.16 g) where the lowest percent (%) reduction over control (7.78%, 9.76% and 23.85% respectively) were obtained with the same treatment.

Benefit/cost ratio (BCR) of various controlling methods for the control of brinjal shoot and fruit borer was considered for the present study. In this study untreated control (T_7) did not required any pest management cost. It is to be noted here that the adjusted net return was the highest (Tk. 402540.00) in T_5 (Marshal 20 EC @ 2ml/L of water) where the lowest (129900.00) was in T_2 (Mehogoni oil @ 3ml/L of water). Similarly, it is revealed that the BCR was the highest (11.45) in T_5 where the lowest was in T_2 (4.85).

It can be concluded from the above analysis that the proportion of infested fruits in the infested category under different treatments would vary greatly in terms of infestation in shoot and fruit cause by brinjal shoot and fruit borer. Therefore an insecticide treatment might be effective in protecting the crop significantly against brinjal shoot and fruit borer.

The study also indicated that among the treatments T_5 (Application of Marshal 20 EC @ 2ml/L of water after 28 days after transplanting and repeated at 7days interval) showed best performance in terms of reduction of shoot infestation, fruit infestation, reduction of infestation intensity, yield protection, yield contributing parameters and BCR. T_6 (Application of Ripcord 10 EC @ 1ml/L of water 28 days after transplanting and repeated at 7days interval) and T_3 (Application of Neem oil @ 5ml/L of water at 28 days after transplanting and repeated at 7days interval) also showed higher performance on different characters under the present study. Considering all the treatments T_3 (Neem oil @ 5ml/L of water) gave comparatively better performance so, the treatment could be considered as an eco-friendly management practice against BSFB.

Hence, the ultimate target of the study is to increase healthy fruit yield and reducing infested yield, from this point of view, among the different treatments Marshal 20EC @ 2ml/L of water (applied at 28 days after transplanting and repeated at 7 days interval) may be recommended for controlling effectively the brinjal shoot and fruit borer.

The present study was carried out at the experimental field of Sher-e-Bangla Agricultural University. Further trial of this study in different locations of the country is needed to justify the results obtained from the present study and for higher return.

CHAPTER VI

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APPENDICES

Appendix I. Monthly average air temperature, relative humidity and total rainfall of the experimental site during the period from October 2009 to July 2010

Month	RH (%)	Max. Temp. (ºC)	Min. Temp. (ºC)	Rain fall (mm)
October	73.36	29.46	19.19	Terract
November	71.15	26.98	14.88	Terrace
December	68.30	25.78	14.21	Terace
January	69.53	25.00	13.46	0
February	50.31	29.50	18.49	0
March	44.95	33.80	20.28	0
April	61.40	33.74	23.81	185
May	64.27	32.5	24.95	180
June	66.24	28.28	25.34	184
July	81	31.4	25.8	542

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1212.

Appendix II: Characteristics of experimental soil was analyzed at Soil Resources Development Institute (SRDI), Farmgate, Dhaka

A. Morphological characteristics of the experimental field

Morphological features	***Characteristics***
Location	Agronomy Farm, SAU, Dhaka
AEZ	Modhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	Not Applicable

Source: Soil Resource Development Institute (SRDI)

B. Physical and chemical properties of the initial soil

Characteristics	**Value**
Partical size analysis	
% Sand	27
%Silt	43
% Clay	30
Textural class	Silty-clay
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI)

Appendix III: Effect of different insecticides on shoot and fruit infestation of brinjal by brinjal shoot and fruit borer

Source of variation	Degrees of Freedom	Mean square		
		% shoot infestation of brinjal	% fruit infestation by number	% fruit infestation by weight
Replication	2	0.003	0.012	0.008
Factor A	6	3.044*	1.205**	4.169*
Error	12	0.233	1.004	1.216

Appendix IV: Effect of different applied insecticides on the yield of brinjal affected by brinjal shoot and fruit borer

Source of variation	Degrees of Freedom	Mean square		
		Healthy yield by weight (t/ha)	Infested Yield by weight (t/ha)	Total Yield by weight (t/ha)
Replication	2	0.014	0.001	0.004
Factor A	6	5.044*	2.224*	8.166*
Error	12	1.233	1.342	2.218

Appendix V: Effect of different treatments on infestation intensity and grading of fruits infested by Brinjal shoot and fruit borer

Source of variation	Degrees of Freedom	Mean square			
		Scale 1	Scale 2	Scale 3	Scale 4
Replication	2	0.001	0.001	0.002	0.001
Factor A	6	6.344*	5.321*	2.246*	0.334**
Error	12	2.118	1.322	0.612	0.235

Appendix VI: Effect of different treatments on yield contributing parameters affected by brinjal shoot and fruit borer

Source of variation	Degrees of Freedom	Mean square		
		Length/fruit (cm)	Girth/fruit (cm)	Edible portion/infested fruit (g)
Replication	2	0.002	0.001	0.001
Factor A	6	6.124*	4.205**	8.116*
Error	12	1.233	0.128	2.216