EFFECTIVENESS OF SOME INSECTICIDES TO CONTROL BRINJAL SHOOT AND FRUIT BORER (*Leucinodes orbonalis* Guenee)

BY

MD. RASHEDUL ISLAM

REGISTRATION NO. 25235/00353

A Thesis
Submitted to the Faculty of Agriculture,
Sher-e-Bangla Agricultural University, Dhaka,
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE (MS)

IN

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SEMESTER: JULY-DECEMBER, 2006

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CERTIFICATE

This is to certify that thesis entitled, "**EFFECTIVENESS OF SOME INSECTICIDES TO CONTROL BRINJAL SHOOT AND FRUIT BORER (*Leucinodes orbonalis* Guenee)**"submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (M. S.) IN ENTOMOLOGY,** embodies the result of a piece of *bona fide* research work carried out by Mr. MD. RASHEDUL ISLAM Roll No. 25235/00353 Registration No. 25235/00353 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, as has been availed of during the course of this investigation has been duly acknowledged.

Dated: December, 2006
Place: Dhaka, Bangladesh

Dr. Md. Serajul Islam Bhuiyan
Professor
Supervisor

DEDICATED TO

MY

HEAVENLY FATHER AND

BELOVED MOTHER

LIST OF ABBREVIATIONS AND SYMBOLS

Full word	Abbreviation
Agro-Ecological Zone	AEZ
And others	*et al.*
Bangladesh Bureau of Statistics	BBS
Centimeter	cm
Coefficient of variation	CV
Days after transplanting	DAT
Degree Celsius	°C
Degrees of freedom	d.f
Et cetera	etc.
Emulsifiable Concentrate	EC
Food and Agriculture Organization	FAO
Figure	Fig.
Gram	g
Hectare	ha
Hydrogen ion conc.	pH
Journal	J.
Kilogram	kg
Least significant difference	LSD
Liter	l
Meter	m
Mean sum of square	MS
Millimeter	mm
Murate of Potash	MP
Number	no.
Percent	%

Full word	Abbreviation
Randomized Complete Block Design	RCBD
Sher-e-Bangla Agricultural University	SAU
Square meter	m^2
Ton	T
Triple Super Phosphate	TSP

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Dated: December, 2006 *The Author*

SAU, Dhaka.

EFFECTIVENESS OF SOME INSECTICIDES TO CONTROL BRINJAL SHOOT AND FRUIT BORER (*Leucinodes orbonalis* Guenee)

By

MD. RASHEDUL ISLAM

ABSTRACT

An experiment was conducted at the Sher-e-Bangla Agricultural University, Bangladesh during December 2005 to May 2006 to evaluate some insecticides for their efficacy to control brinjal shoot and fruit borer (*Leucinodes orbonalis* Guenee). The study comprising five treatments including a control and laid out in a Randomized Complete Block Design (RCBD).

Among the treatments, T_3 (Marshal 20 EC applied at 28 days after transplanting and repeated at 7 days interval) performed best results in terms of reduction of shoot infestation, fruit infestation and infestation intensity, as well as yield protection. It ensured 65.18% reduction in shoot infestation over control and had only 2.74% shoot infestation. Maximum reduction in fruit infestation (95.38%) was obtained in T_3 over control. It also ensured the highest yield of 24.55 t/ha with maximum increase (163.75%) of healthy fruit yield. This was followed by T_4, T_2 and T_1 giving significantly lower yield such as 21.95 t/ha, 21.25 t/ha and 19.44 t/ha respectively having no significant difference in T_2 with T_1 and T_2 with T_4 where the control was 15.88 t/ha. The infested fruit belonging to Scale 4 was nil and Scale 1 was 50.00% in T_3. While those belonging to Scale 1 was 47.06%, 44.44% and 41.18% in T_1, T_4 and T_2 respectively as against 12.50% to Scale 4 and 37.50% to Scale 1 in control. The Benefit Cost Ratio (BCR) was the highest (21.33%) in case of T_4 which was much higher than all other treatments.

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Chapter I

Introduction

CHAPTER I

INTRODUCTION

Bangladesh is predominantly an agricultural country. Agriculture contributes about 42% of total GDP in Bangladesh. Approximately 24% of the GDP is derived from cereal crops and vegetables. Although Bangladesh has become near self-sufficient in the production of cereal crops for last few years. But Bangladesh has a serious deficiency in vegetables. Vegetables are very important crops in the world. Vegetables constitute important items in our daily diet, as they are important source of vitamins, minerals, and plant proteins. But the annual vegetable production in Bangladesh is only 942000.00 metric tons including potato and sweet potato from 150000.00 hectare land (Anonymous, 2005). Though, the optimum daily requirement of vegetables for a full-grown person is 205 g yet the per capita consumption is only 32 g in this country (Hossain *et al.* 1990; Ramphall and Gill 1990). As a result, chronic malnutrition is commonly evident in Bangladesh.

Among different kinds of vegetables, brinjal (*Solanum melongena* Linnaeus) is one of the most popular and principal vegetable crops grown in Bangladesh and other parts of the world. Brinjal covers an area of 29,960 hectares, which is about 14.92% of total vegetable area of the country, and its production is about 3,82,000 tons during the year 2000 (Anonymous, 2003). More than 70% of the total vegetables are produced in Rabi season and less than 30% of it is grown in Kharif season (Hossain and Awrangzeb, 1992). Usually the vegetables production in Kharif seasons is very low in Bangladesh and thus brinjal may play an important role in this season (Anonymous, 1995a).

Brinjal is also known as eggplant or aubergine or melanzane which belongs to the family Solanaceae (Thompson, 1951). This crop is the second most important vegetable crop after potato in Bangladesh and is equally preferred by both rich and poor people (Anonymous, 1994a). Brinjal is easily grown throughout the year in Bangladesh. Mostly it is cultivated in winter season and requires continuous long warm weather during growth and fruit maturation. The optimum growing temperature is 22°-32°C and growth stops at temperature below 17°C (Yamaguchi, 1983).

Brinjal is extensively grown in Bangladesh, India, Pakistan, China and Philippines. It is also popular in other countries like Japan, Indonesia, Turkey, Italy, France, United States, Mediterranean and Balkan area (Bose and Som, 1986). It was probably a native wild plant of India (Purewal, 1957; Splittstoesser, 1979). The domesticated types of brinjal spread eastward from India to China by fifth century B, C, (Yamaguchi, 1983).

Brinjal has a good nutritive value. 100gm of edible portion of brinjal fruit contains 92.7g water, 1.4g protein, 0.3g fat, 0.3g minerals, 1.3 g fibre, 4.0 g carbohydrates, 18.0 mg calcium, 16.0 mg magnesium, 18.0 mg oxalic acid, 47.0 mg phosphorus, 0.9 mg iron, 3.0 mg sodium, 2.0 mg potassium, 0.17mg copper, 44.0mg sulfur, 52mg chlorine, 124 I.U. vitamin A, 0.04 mg thiamin, 0.11 mg riboflavin, 0.09 mg nicotinic acid and 12.0 mg vitamin (Choudhury, 1992).

Brinjal is attacked by various insects from seedling to last harvest of the fruits. Nayar *et al.*, (1995) reported that this crop is attacked by 53 species of insect pests. About eight insect species are considered as major pests causing damage to the crop and the remaining ones including one species of mite are considered as minor pests (Biswas *et al.*, 1992). Various insects pests cause enormous losses to brinjal in every season and every year in Bangladesh (Alam, 1969). The losses caused by these pests vary from season to season depending upon environmental factors (Patel *et al.*, 1988). Brinjal shoot and fruit borer (BSFB) *Leucinodes orbonalis* Guenee (Lepidoptera: Pyralidae) is the most obnoxious and detrimental pest of brinjal in Bangladesh (Nair, 1986; Chattopadhyay, 1987; Nayar *et al.*, 1995) and India (Tewari and Sardana, 1990) and also considered as a major pest in other brinjal growing countries of the world (Dhanker, 1988).

Larval stage of this pest causes the most damage. The pest is active throughout the year at places having moderate climate but its actively is adversely affected by severe cold. This pest also attacks potato, tomato, peas (Hill, 1983), and other Solanaceous crops and wild *Solanum* species (Karim, 1994). It is very active in summer, especially in the rainy season and less active during February to April. The yield loss has been estimated up to 86% (Ali *et al.*, 1980) and 67% (Islam and Karim, 1991) in Bangladesh and more than 90% (Kallo, 1988), and 63% in Haryana, India (Dhankar, 1988). The infestation ranged from 12 to 16% for shoot (Alam *et al* ., 1964) and 20 to 86% for fruit in Bangladesh (Ali *et al.,* 1980), and the percentage of fruit infestation and crop loss caused by this pest ranged from 37 to 63% in different states of India (Dhankar, 1988). The percent infestation of fruits is more than that of the shoots (Alam and Sana, 1962).

The damage caused by BSFB starts at seedling stage and continues till the last harvest of the fruits. In young plants, the newly hatched larvae bore into the petioles and midribs of 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 drop out due to their feeding which caused disruption of vascular system and ultimately wither (Alam and Sana; 1962). At later stage of the plant growth, the larvae bore generally through the calyx and later into the flower buds and the fruits without leaving any visible sign of infestation and feed inside (Butani and Jutwani, 1984). The infested flower buds become dry and shed. At fruiting stage, they prefer to bore into the fruits. The larvae feed on the pith tissues of infested fruits by boring tunnels. Infested fruits show exit holes along with excreta. A caterpillar may destroy 4-6 fruits during the larval period (Atwal, 1986). When an infested fruit is cut open, black excreta, moulds and sometimes rotten portion is found. The secondary infection caused by certain bacteria further deteriorates the fruits and the fruits become unfit for human consumption (Islam and Karim, 1994). Vitamin C (ascorbic acid) is also reduced to the extent of 68% in infested fruit (Hami, 1955). Many factors may be responsible for the severe infestation of insect pests in brinjal field. Among them climate, uncontrolled application of urea, close planting, time of planting etc. are important.

Now it has been substantiated that the brinjal shoot and fruit borer is a major problem in brinjal cultivation worldwide. But its management still remains unsolved. The information on environmentally friendly management tools for the management of this is scanty. Considering the importance of this pest a wide range of Organophosphorus, Carbamates and Synthetic pyrethroids with various spray formulations have been suggested from time to time against this pest (Yein, 1985; Prakash, 1988; Temurde *et al.*, 1992; Islam and Karim, 1993). The indiscriminate use of insecticides against the pest cause several problems viz., insecticide resistance, toxic residues in fruits, killing of natural enemies and ultimately pest resurgence. As a consequence of both overuse and abuse of insecticides, a large number of agricultural pests have demonstrated the ability to become resistant to all classes of organic chemical insecticides and resistance has been found to occur worldwide (Dennely *et al.*, 1990; Lemon, 1990; Gunning *et al.*, 1984). Considering the increasing threat of developing resistance, the worker of pest management programme of several countries (e.g. USA, Canada, Australia etc.) have undertaken long term programme to develop appropriate resistance management (RM) strategies as a part of IPM (Forrester, 1990). The suppression of this pest by other alternative non-chemical approaches like cultural, mechanical, biological, host plant resistance, grafting techniques etc. in Bangladesh and some other parts of the world is limited. Thus the information on non-chemical control measures of this pest is barely sufficient. However, Bangladesh Agricultural Research Institute (BARI), Sher-e-Bangla Agricultural University (SAU), Bangladesh Agricultural University (BAU), Bangabandhu Sheikh Majibur Rahman Agricultural University (BSMRAU) are trying to find out suitable integrated approaches to control brinjal shoot and fruit borer (Anonymous, 1994). Hand picking of infested shoot and fruit and dusting ash on leaves to manage this pest were tried as component of IPM (Anonymous, 1995a). Grafting technique was found partially effective in reducing BSFB infestation when *Solanum torvum* used as rootstock (Alam *et al.*, 1994). Khorsheduzzaman *et al.*, (1998) used grafted brinjal plants, neem oil, mechanical method in combination with insecticides and obtained results with varying level of success. Two pupal parasitoids (*Cremastus flavo-orbitalis* and *Itamoplex sp)* have been recorded parasitizing BSFB. About 9-15% pupae that were collected from the field were parasitized (Verma and Lal, 1985). So far no botanicals were found to be effective against this pest.

With the ever increasing world population demand for food and the intensified drive for food production call for the greater use of agro chemicals. The use of insecticides has become indispensable in increasing vegetable crop production because of its quick effect, ease of application and availability. The review reveals that of the available pest control techniques, chemical means are still prime and provide a rapid, cost-competitive, typically effective and valuable pest management weapon. Due to inadequate knowledge and availability of non-chemical pest management approach, brinjal growers of Bangladesh mostly depend on chemicals to keep the crop production steady. It has been documented that about 70% farmers of greater Jessore region of Bangladesh spray insecticides to brinjal at every alternate day and 41-84 sprays are applied in a single season (Anonymous, 1994).

At present, organophosphorus, carbamates and synthetic pyrethroids are being widely used to control brinjal shoot and fruit borer (*Leucinodes orbonalis* Guenee) a serious pest of brinjal. But their actual efficacy are not known.

Therefore, the present study was undertaken with the following objectives:

i. To evaluate the effectiveness of some selected insecticides against the brinjal shoot and fruit borer.

ii. To know the population dynamics of brinjal shoot and fruit borer in the field.

iii. To determine the Benefit Cost ratio of applied insecticides.

Chapter II

Review of literature

CHAPTER II

REVIEW OF LITERATURE

Brinjal (*Solanum melongena* L.) 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. 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 (BSFR), *Leucinodes orbonalis* Guenee is the most destructive pest of brinjal in Bangladesh (Alam, 1969; Chattopadhyay, 1987). The damage caused by the pest either sporadically or in epidemic form every year all over Bangladesh. The incidence of the pest varies from 12-63% in shoots and 20-63% in fruits (Alam, 1969) and as a whole up to 70% loss is caused to the crop (Nair, 1986) and up to 23% loss is caused in fruit weight (Singh, 1984). Thus the crop is made totally unfit for human consumption.

For the management of this pest, two approaches are followed in Bangladesh. One of them is clean cultivation involving removal of infested shoots and fruits. The other is the application of synthetic chemicals at 7-15days 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). The indiscriminate use of chemicals particularly in vegetables is apprehended to create several problems including health hazards to the consumers. The national recommendation of an insecticide should be made based not only on its pest control efficacy but also taking into consideration its safety factors supported by adequate residue data. However, no information on the residues of Synthetic pyrethoids and Carbamates on brinjal seem to be available in Bangladesh. Reviews of the available literature relevant to the key aspects of this study including the target pest, it's management have been made which are presented below:

2.1. General feature of brinjal shoot and fruit borer

2.1.1. Origin and Distribution

At first Guenee describes brinjal shoot and fruit borer as *Leucinodes orbonalis* in 1854. Walker designated it as the type species of the genus in 1859. There is no known synonym of *Leucinodes orbonalis*, but several other species of *Leucinodes* have been described. 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 spead 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 translocatioin 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.

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.

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.

Kumar and Sadashiva (1996) observed that resistance of *Solanum macrocarpon* to *L. orbonalis*, while the incidence of *L. orbonalis* on cultivated brinjal varieties was 10-50%. Less than 1% of *S. macrocarpon* fruits was damaged by *L. orbonalis*. 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).

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).

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).

Mehto and Lal (1981) found that the relative susceptibility of several cultivars of brinjal to infestation by *L. orbonalis*. The minimum infestation of shoots (7.70%) and fruits (6.77%) was observed in the variety Long purple, which was more resistant to the pest than the other cultivars.

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

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%). 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.

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.

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.

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).

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 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).

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 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).

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).

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.

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).

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).

2.2.5. Control with 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, Fenpropath rin, 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.

Chapter III

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

The experiment comprising four selected insecticides was carried out at the Horticulture Farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh during the period from December 2005 to June 2006. The materials required and methology followed are described below under following sub-headings.

3.1. Location

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

3.2. Climate

The climate of the experimental site is subtropical, characterized by heavy rainfall during the month of April to May, 2006. 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 (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 (appendix II).

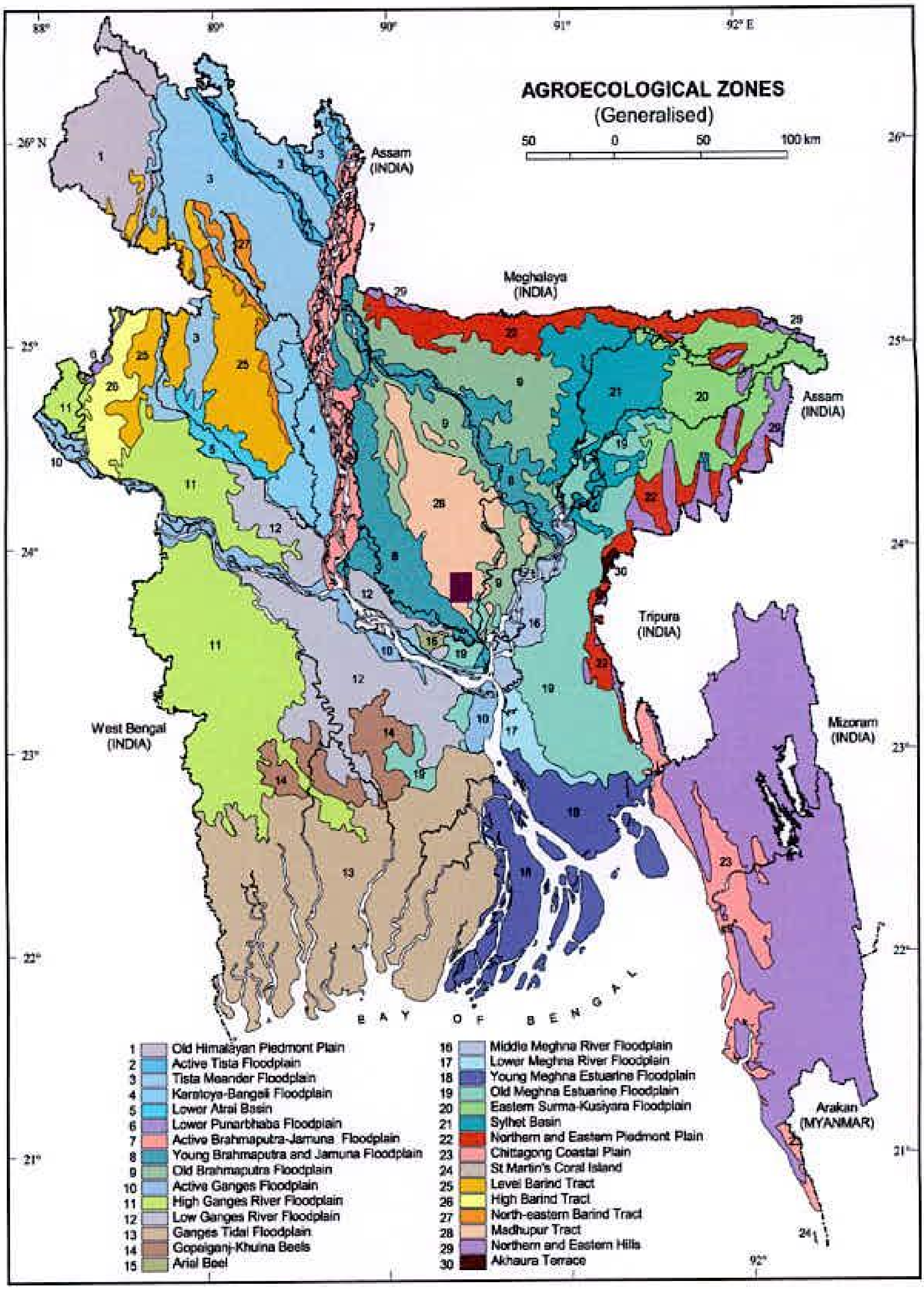

Plate 1. Location of experimental field ■

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 four replications in the field of the Horticulture Farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh.

3.5. Land preparation

The land was well 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 M.P, respectively per hectare. The full dose of cow-dung, TSP and a half of MP were applied as basal dose during land preparation, the entire dose of urea and rest of MP 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 MP at the of flowering initiation followed by last top dressing comprising rest of urea and MP at the time of fruit initiation. The whole field was divided into five equal size blocks having 1 m space between the block and each block was again sub-divided into 4 plots (3m x 3m each) with 1 m space between the plots, eighteen pits were made in each plot at a distance of 100 cm between rows and 50 cm 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 1 m was prepared and seeds were shown on 21 December, 2005. Fourty days-old healthy seedlings were transplanted on 31 January, 2006 in the main field. A total of 360 seedlings were transplanted in 20 plots at the rate of 18 seedlings per plot.

3.7. Cultural Operations

Pits having transplanted seedlings were immediately irrigated lightly 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 MP and Urea fertilizers were top dressed in 3 splits as described earlier.

3.8. Details of Treatments

Effectiveness of four treatments to reduce shoot and fruit borer infestation in brinjal was evaluated against control having no insecticide. The treatments and the control thus included in the study were as follows:

T_1= Application of Cymbush 10EC @ 500 ml/ha at 28 days after transplanting and repeated at 7days interval.

T_2 = Application of Ripcord 10 EC @ 500 ml/ha at 28 days after transplanting and repeated at 7days interval.

T_3 = Application of Marshal 20 EC @ 1500 ml/ha at 28 days after transplanting and repeated at 7days interval.

T_4 = Application of Chlorpyrifos 20 EC @ 1000 ml/ha at 28 days after transplanting and repeated at 7days interval.

T_5 = Untreated control.

3.9. Insecticides Application

Cymbush 10 EC, Ripcord 10 EC, Marshal 20 EC and Chlorpyrifos 20 EC were collected from the Mirpur market of Dhaka district @ Tk 61 per 50 ml bottle, Tk 64 per 50 ml bottle, Tk 80 per 100 ml bottle and Tk 60 per 100 ml bottle respectively. Cymbush 10 EC was applied by mixing 0.50ml of insecticide with 1 liter of water per plot. Ripcord 10 EC was applied by mixing 0.50 ml of insecticide with 1 liter of water per plot. Marshal 20 EC was applied by mixing 1.50 ml of insecticide with 1 liter of water per plot. Chlorpyrifos 20 EC was applied by mixing 1.00 ml of insecticide with 1 liter of water per plot. The mixture within the spray machine was shaken and sprayed covering the whole plants. Four liters spray material was required to spray four plots. The spraying was done in the afternoon to avoid bright sunlight and drift caused by strong wind and adverse effect of pollinating bees.

3.10. Monitoring of infestation

For the purpose of determining the incidence of adults and the level of infestation for 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 9 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.

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

Plate 3. Infested shoot with brinjal shoot and fruit borer larva feeding inside

Plate 4. Infested fuit with brinjal shoot and fruit borer larva feeding inside

Plate 5. Female brinjal shoot and fruit borer laying eggs on the lower surface of a brinjal leaf

Plate 6. Larva of brinjal shoot and fruit borer

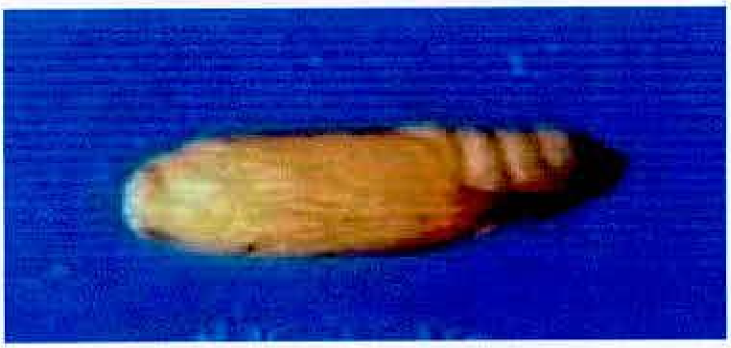

Plate 7. Pupa of brinjal shoot and fruit borer

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 9 plants from each plot at 7 days intervals during the period from 20 February, 2006 to 30 May, 2006. 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 9 plants. Twelve harvests were done throughout fruiting season i.e., during 21 February, 2006 to 30 May, 2006. 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 9 sample plants of 12 harvests have been summed up plot wise and then transformed into per plot healthy fruit yield and infested fruit yield simply by calculating the same for 18 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 per 9 sample plants at each harvest were counted 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:

$$\% \text{ of scale I} = \frac{\text{Number of infested fruits belonging to scale i}}{\text{Total number of infested fruits}} \times 100$$

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, 7 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 was measured in g 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 above cut open sample fruit belonging to each scale were cut separated and weighed in g from which the average damage weight was calculated.

Fresh weight: For measuring the fresh weight the portion except the damaged portion of the above sample fruits were weighed in g 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). Graphs have been prepared wherever needed for presenting the results.

Chapter IV

Results and Discussion

CHAPTER IV

RESULTS AND DISCUSSION

The comparative effectiveness of the selected four 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

The comparative effectiveness of various treatments on shoot infestation by the brinjal shoot and fruit borer has been evaluated in terms of their efficacy in reducing the shoot infestation over control expressed in percent as presented in Table 1.

As shown in Table 1, the shoot infestation was the lowest (2.74%) in the plots treated with Marshal 20EC at 28 days after transplanting and repeated 7 days interval (T_3). The second lowest shoot infestation (4.36%) was observed in the plots treated with Chlorpyrifos 20EC at 28 days after transplanting and repeated 7 days interval (T_4) and shoot infestation of 5.13% was observed in the plot having Ripcord 10EC applied at 28 days after transplanting and repeated 7 days interval (T_2) which was close to T_4. The highest shoot infestation of 6.02% was observed in the plots having Cymbush 10EC which was close to control plot (T_5) that having 7.87% shoot infestation.

Thus it is seen from the same Table 1 that Marshal 20EC gave the significantly highest reduction in shoot infestation (65.18%) over control (T_3). This was followed by a 44.60%, 34.82% and 23.50% reduction in shoot infestation over control achieved by Chlorpyrifos 20EC (T_4), Ripcord 10EC (T_2), and Cymbush 10EC (T_1), applied at 28 days after transplanting and repeated 7 days interval respectively.

The comparison of the results of present study with the existing findings shows that although significant reduction in shoot infestation was achieved over control, none of the treatments was able to exceed the efficacy reported by others who found about 80% reduction in shoot infestation over control. Kabir *et al.* (1994) observed similar results where the chemical insecticide was not very effective against brinjal shoot and fruit borer.

Table 1. Effect of different insecticides on shoot infestation of brinjal by brinjal shoot and fruit borer

Treatments	Dose (ml/ha)	No. of application	* % Shoot infestation	* Reduction of shoot infestation over control
T_1	500	12	6.02 b	23.50
T_2	500	12	5.13 c	34.82
T_3	1500	12	2.74 e	65.18
T_4	1000	12	4.36 d	44.60
T_5	--	12	7.87 a	--
$LSD_{(0.005)}$		--	0.578	--
CV (%)		--	7.19	--

T_1= Application of Cymbush 10EC @ 500 ml/ha at 28 days after transplanting and repeated at 7days interval.

T_2 = Application of Ripcord 10 EC @ 500 ml/ha at 28 days after transplanting and repeated at 7days interval.

T_3 =Application of Marshal 20 EC @ 1500 ml/ha at 28 days after transplanting and repeated at 7days interval.

T_4 =Application of Chlorpyrifos 20 EC @ 1000 ml/ha at 28 days after transplanting and repeated at 7days interval.

T_5 = Untreated control.

* Mean value of 4 replications; each replication is derived from 9 plants per treatment.

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

4.2. Shoot infestation fluctuation of brinjal shoot and fruit borer on brinjal shoot in relation to temperature

Weekly observations on the per cent shoot infestation fluctuation with temperature are presented in Figure 1. The Figure shows that the infestation of brinjal shoots starts from 35 days after transplanting and peaked on 7 March, 2006. The infestation was low on 21 March, 2006 which was related with the low temperature. After that the infestation gradually increased with the increase of temperature. The results indicated positive correlation prevails between temperature and the brinjal shoot and fruit borer population. Higher temperature favors the population size while lower temperature retards the growth and development of the brinjal shoot and fruit borer. Maleque (1998) studied that the population of the brinjal shoot and fruit borer is positively correlated with average temperature, mean relative humidity and total rainfall.

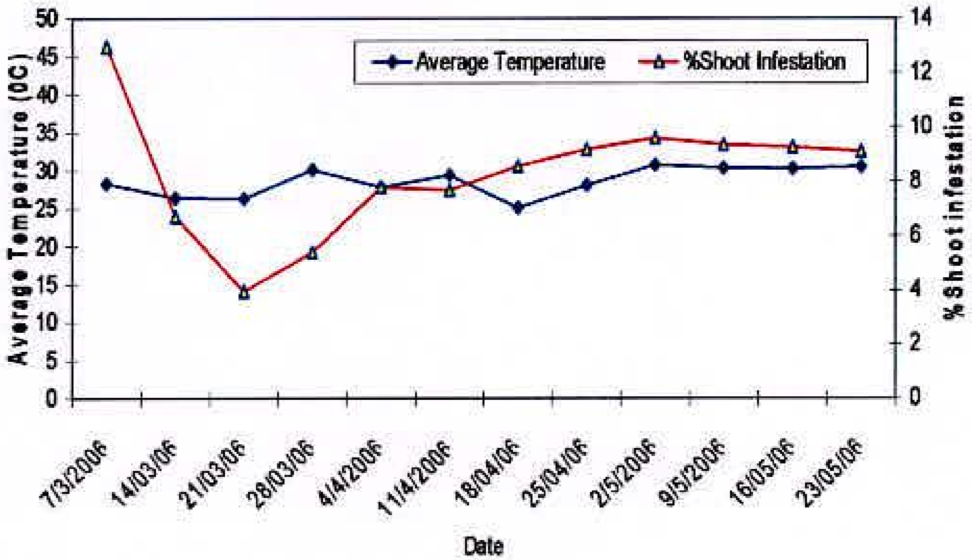

Figure 1. Percent shoot infestation in relation to temperature caused by brinjal shoot and fruit borer in control plot.

4.3. 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 per cent fruit infestation by number and weight as well as in per cent reduction in infestation over control is presented in Table 2.

The result showed that the lowest fruit infestation of 3.15% by number and 4.28% by weight was observed in T_3 (spray with Marshal 20EC @ 1.5 ml/l of water at 7 days intervals), followed by 8.20%, 21.06% and 24.22% by number and 9.34%, 21.82% and 24.34% by weight in T_4 (spray with Chlorpyrifos 20EC @ 1 ml/l of water at 7 days intervals), T_2 (spray with Ripcord 10EC @ 0.5 ml/l of water at 7 days intervals) and T_1 (spray with Cymbush 10EC @0.5 ml/l of water at 7 days intervals), respectively which also significantly differed from all other treatments. All these treatments differed most significantly from untreated control treatment, T_5 that recorded the highest fruit infestation (68.11% by number and 44.22% by weight). The rest of the treatments (T_1, T_2 and T_4) had the intermediate level of infestation by number (24.22% 21.06% and 8.20%) and by weight (24.34%, 21.82% and 9.34%) differing significantly from each other.

In terms of reduction in fruit infestation over control, Marshal 20EC (T_3) sprayed at 7 days intervals @ 1.5 ml/l of water provided the highest reduction in fruit infestation (95.38% by number and 90.32% by weight) over untreated over control (T_5). This was followed by T_4 (87.96%), T_2 (69.08%) and T_1 (64.44%) in respect of reduction of fruit infestation by number, and T_4 (78.88%), T_2 (50.66%) and T_1 (44.96%) in respect of reduction of fruit infestation by weight. Thus the treatment T_3 was able to exceed the standard level of 80% reduction in fruit infestation over control by both number and weight. The treatment T_4 that only by number, none of the treatments was able to exceed the standard level of 80% reduction in fruit infestation over control.

The results thus obtained in the present study when compared to the findings reported by other workers suggest that all the treatments including the one which achieved the highest reduction of 95.38% by number and 90.32% by weight were less effective in reducing the fruit infestation as compared to those reported by them. Arrivo and Bestox achieved 56.94% and 51.33% reduction of fruit infestation respectively over control (Anonymous, 1995). 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 fruit to shoots during the fruiting stage.

Table 2. Effect of different insecticides on fruit infestation of brinjal

Treatments	Dose (ml/ha)	No. of application	* (%)Fruit infestation		*(%) Reduction of fruit infestation	
			By number	By weight	By number	By weight
T_1	500	12	24.22 b	24.34 b	64.44	44.96
T_2	500	12	21.06 c	21.82 b	69.08	50.66
T_3	1500	12	3.15 e	4.28 d	95.38	90.32
T_4	1000	12	8.20 d	9.34 c	87.96	78.88
T_5	--	12	68.11 a	44.22 a	--	--
$LSD_{(0.005)}$	--	--	0.509	3.723	--	--
CV (%)	--	--	17.11	11.62	--	--

T_1= Application of Cymbush 10EC @ 500 ml/ha at 28 days after transplanting and repeated at 7days interval.

T_2 = Application of Ripcord 10 EC @ 500 ml/ha at 28 days after transplanting and repeated at 7days interval.

T_3 =Application of Marshal 20 EC @ 1500 ml/ha at 28 days after transplanting and repeated at 7days interval.

T_4 =Application of Chlorpyrifos 20 EC @ 1000 ml/ha at 28 days after transplanting and repeated at 7days interval.

T_5 = Untreated control

* Mean value of 4 replications; each replication is derived from 9 plants per treatment.

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

4.4. Per cent Shoot and Fruit Infestation

During the fruiting season it had been observed that the per cent shoot infestation was relatively lower than the fruit infestation (Figure 2). This was perhaps due to the reason that the insect prefers fruits than shoots during the fruiting period. The similar observation was done by Maleque (1998) that the caterpillar prefers the fruits during fruiting stage of the plant which is similar with the above results. Alam and Sana (1962) observed that the infestations of fruits are greater than that of the shoots during the fruiting period.

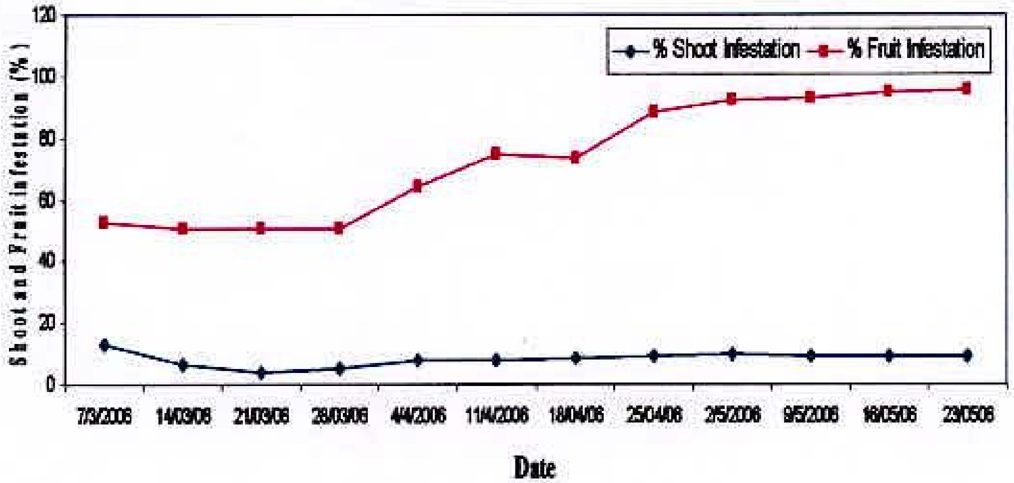

Figure 2. Percent shoot and fruit infestation in control

4.5. 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.

The results thus presented in Table 3 shows that the total fruit yield was maximum (24.55 t/ha) in case of Marshal 20EC applied at 28 days after transplanting and repeated at 7 days intervals (T_3) followed by significantly lower yield (21.95 t/ha) in case of T_4 (Chlorpyrifos 20EC applied at 28 days after transplanting and repeated at 7 days intervals). T_2 (21.25 t/ha) and T_4 (21.95 t/ha), T_1 (19.44 t/ha) and T_4 (21.95 t/ha) have no significant difference with each other but T_4 (21.95 t/ha) and T_1 (19.44 t/ha) have significant difference with each other. Thus it is observed that application of Cymbush 10EC was not enough to protect the fruit yield from the pest attack. This is further clear from the same Table which shows that the yield of infested fruit was maximum (4.72 and 4.64 t/ha) in T_1 and T_2 having no significant difference between themselves but they have significant difference with control. On the other hand, the yield of infested fruit was minimum (1.05 t/ha) in case of T_3 (Marshal 20EC) followed by (2.05 t/ha) in case of T_4 (Chlorpyrifos 20EC). Accordingly, the yield of healthy fruit was the highest (23.50 t/ha) in T_3 while it was significantly lower (19.90 t/ha) in T_4 followed by 16.61 t/ha in T_2 and 14.72 t/ha in T_1. T_1 and T_2 have no significant difference between themselves but significantly different from control. On the other hand, T_3 and T_4 were significantly different form each other. Control had only 8.91 t/ha healthy fruit yield.

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_3 ensured maximum increase (163.75%) of healthy fruit yield followed by significantly less increase (123.34%) in T_4 and 86.42% in T_2 and 65.21% in T_1. Conversely, maximum reduction (84.94%) in infested fruit yield was observed in T_3 while it was lower in T_4 (70.59%) followed by T_2 and T_1. Accordingly, as a cumulative impact, maximum increase in total fruit yield was observed in T_3 (54.60%) followed by 38.22% in T_4.

Table 3. Effect of different insecticides on yield increase/decrease over control plot

Treatments	Dose (ml/ha)	No. of application	Healthy Yield		Infested Yield		Total Yield	
			(t/ha)	Increase (+)/decrease (-) over control (%)	(t/ha)	Increase (+)/decrease (-) over control (%)	(t/ha)	Increase (+)/decrease (-) over control (%)
T_1	500	12	14.72 c	+65.21	4.72 b	-32.28	19.44 c	+22.42
T_2	500	12	16.61 c	+86.42	4.64 b	-33.43	21.25 bc	+33.82
T_3	1500	12	23.50 a	+163.75	1.05 d	-84.94	24.55 a	+54.60
T_4	1000	12	19.90 b	+123.34	2.05 c	-70.59	21.95 b	+38.22
T_5	--	--	8.91 d	--	6.97 a	--	15.88 d	--
$LSD_{(0.005)}$	--	--	1.917	--	0.441	--	2.083	--
CV (%)	--	--	7.44	--	7.39	--		--

T_1= Application of Cymbush 10EC @ 500 ml/ha at 28 days after transplanting and repeated at 7days interval.
T_2 = Application of Ripcord 10 EC @ 500 ml/ha at 28 days after transplanting and repeated at 7days interval.
T_3 =Application of Marshal 20 EC @ 1500 ml/ha at 28 days after transplanting and repeated at 7days interval.
T_4 =Application of Chlorpyrifos 20 EC @ 1000 ml/ha at 28 days after transplanting and repeated at 7days interval.
T_5 = Untreated control.

* Mean value of 4 replications; each replication is derived from 9 plants per treatment.

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

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 Cypermethrin and Carbofuran used in controlling the pest. Such as Khaire *et al.* (1986) reported that the best control of brinjal shoot and fruit borer and the highest yield of marketable fruits (91.1 q/ha) were ensured by 0.015% Cypermethrin applied at flowering and repeated 4 times at 10 days intervals as against only 13.5 q/ha marketable fruits in control. Similarly, 3 to 4 spray of Cypermethrin 10 EC or Cyfluthrin (Bethroid) 50 EC @ 1.0 ml per liter of water or Fenvalerate 20 EC @ 0.5 ml per liter of water at an interval of 15 days starting from the first (lowering was found effective in controlling the brinjal shoot and fruit borer in Bangladesh (Anonymous, 199la). Agnihotri *et al.*, (1990) in evaluation found Cypermethrin (0.01%) and Deltamethrin (0.00125%) as the most effective against the infestation of brinjal shoot and fruit borer on two cultivars, Pusa Kranti and Pusa purple long of Brinjal in India. Nath and Chakraborty (1980) likewise reported that Carbofuran at 6 kg a.i./ha effectively reduced the incidence of brinjal shoot and fruit borer at all stages of crop growth, and also gave a yield increase of about 73%. Pawar *et al.*, (1987) reported that Carbofuran applied at 50 kg a.i./ha 10 days after transplanting, followed by either 3 sprays with 0.006% Cypermethrin at 14 days intervals starting 52 days after transplanting or 5 sprays with Cypermethrin at 14 days intervals starting 10 days after transplanting provided economic control of brinjal shoot and fruit borer.

4.6. Effect of Different Treatments on Infestation Intensity, Extent of Damage and Weight per Fruit

4.6.1. Effect on Infestation Intensity per Fruit

The effects of different treatments on the infestation intensity per fruit expressed in terms of per cent 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, $\geq$7 bores/fruit) are presented in Table 4. It is seen from the Table that among the infested fruits those belonging to Scale 4 was only 11.76% and 11.76% in T_1 and T_2, respectively having no significant difference between them but T_3 and T_4 had no infested fruit, as against 12.50% in control. While those belonging to Scale 3 was 23.53% in T_1 and 23.53% in T_2 and 22.22% in T_4 having no significant difference among them and also T_4 and control had no significant difference between them. But incase of T_3 (16.67%) and control which significantly differed from each other. Similarly, the infested fruits belonging to Scale 2 followed the same trend but with considerably higher value in all the cases except in T_1 (17.65%) such as 33.33% in T_4 having no significant difference with T_3 and T_2 (23.53%) having significant difference with control. The most significant finding is that considerably a very high proportion of infested fruits (50.00%) belonged to Scale 1 in T_3 having significant difference with 37.50% in control. on the other hand T_1(47.06%), T_4 (44.44%) and T_2 (41.18%) having significantly higher bores per fruit over control (37.50%).

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

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

Treatments	Per cent of infested fruits belonging to different scales			
	Scale 1	Scale 2	Scale 3	Scale 4
T_1	47.06 b	17.65 d	23.53 a	11.76 b
T_2	41.18 d	23.53 c	23.53 a	11.76 b
T_3	50.00 a	33.33 a	16.67 c	0.00 c
T_4	44.44 c	33.33 a	22.22 ab	0.00 c
T_5	37.50 e	29.17 b	20.83 b	12.50 a

T_1= Application of Cymbush 10EC @ 500 ml/ha at 28 days after transplanting and repeated at 7days interval.

T_2 = Application of Ripcord 10 EC @ 500 ml/ha at 28 days after transplanting and repeated at 7days interval.

T_3 =Application of Marshal 20 EC @ 1500 ml/ha at 28 days after transplanting and repeated at 7days interval.

T_4 =Application of Chlorpyrifos 20 EC @ 1000 ml/ha at 28 days after transplanting and repeated at 7days interval.

T_5 = Untreated control

Scale 1 (Low intensity) : 1-2 bore/fruit
Scale 2 (Moderate intensity) : 3-4 bore/fruit
Scale 3 (High intensity) : 5-6 bore/fruit
Scale 4 (Very high intensity): ≥ 7 bore/fruit

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_3, 3.15% fruits were found infested of which a very big proportion i.e., 50.00% belonged to Scale 1 (only 1-2 bores/fruit) while a very small proportion, i.e., only 16.67% 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 68.11% infested fruits in control of which a small proportion i.e., only 37.50% belonged to Scale 1(1-2 bores per fruit) while a large proportion i.e., 20.83% belonged to Scale 3 (5-6 bores per fruit) and 12.50% belonged to Scale 4 (>7 bores per fruit). Thus although the effect of T_4 in terms of fruit infestation irrespective of infestation intensity i.e., irrespective of the number of bores per fruit, was not so significant compared to control, its effect in terms of reducing the fruit infestation was highly significant. The results obtained in the present study was similar with that of the Kabir *et al.*, (2003) who reported that Marshal 20EC provided >80% reduction of infestation over control.

4.6.2. Relationship between Infestation Intensity and Fruit Size/Extent of Damage/ Yield

To observe the significance of infestation intensity i.e. the number of bores per fruit as a measure of effect of various treatments, the effect of infestation intensity on the size, yield and extent of damage has been analyzed. To this effect, the size, weight and damaged portion of the fruits sorted out under different Scales have been recorded, analyzed and presented in Table 5. It is revealed from the Table that the infestation intensity has quite a significant effect on the size, extent of damage and weight of the fruit. The Table shows that the fruits belonging to Scale 4 differ quite significantly in size, damaged area, total weight, damaged weight and fresh weight from those belonging to Scale 1. Such as the fruits belonging to Scale 4 are of very small size (length-12.55 cm, girth- 3.02 cm; weight- 35.66 g), have suffered considerably more damage (damaged length-16.87 cm, damaged weight- 11.97 g) and have very low edible yield (23.69 g only) as compared to those belonging to Scale 1 which are of much bigger size (length-17.95 cm, girth- 3.98 cm; and weight- 69.58 g), have suffered less damage (damaged length- 11.48 cm, damaged weight- 9.23 g) and have much more edible yield (60.35 g). Similarly, the infestation intensity corresponding to Scale 3 also had significant effect in reducing the size (length- 15.91 cm, girth- 3.25 cm, weight- 48.22 g), damage (damaged length-15.02 cm, damaged weight- 8.89 g) and edible weight (39.33 g) of the fruit as compared to Scale 1. The infestation intensity corresponding to Scale 2 had statistically similar effect as Scale 3, except on edible weight which was much higher (49.66 g) in Scale 2 than Scale 3.

Table 5. Effect of infestation intensity per fruit caused by Brinjal shoot and fruit borer on the fruit size, extent of damage and fruit yield of brinjal

Infestation intensity	Total length (cm)	Girth (cm)	Total weight (g)	Damage length (cm)	Damage weight (g)	Fresh weight (g)
Scale 1	17.95 a	3.98 a	69.58 a	11.48 b	9.23 c	60.35 a
Scale 2	16.08 b	3.54 b	60.25 b	14.95 a	10.59 b	49.66 b
Scale 3	15.91 b	3.25 c	48.22 c	15.02 a	8.89 c	39.33 c
Scale 4	12.55 c	3.02 d	35.66 d	16.87 a	11.97 a	23.69 d

Scale 1 (Low intensity) : 1-2 bore/fruit
Scale 2 (Moderate intensity) : 3-4 bore/fruit
Scale 3 (High intensity) : 5-6 bore/fruit
Scale 4 (Very high intensity): ≥ 7 bore/fruit

Table 6. Yield and edible yield of brinjal under different Scale of infestation intensity per fruit

Infestation intensity	Total weight (g)	Fresh weight (g)	% Reduction in edible yield
Scale 1	69.58 a	60.35 a	13.27 c
Scale 2	60.25 b	49.66 b	17.58 b
Scale 3	48.22 c	39.33 c	18.44 b
Scale 4	35.66 d	23.69 d	33.57 a

Scale 1 (Low intensity) : 1-2 bore/fruit

Scale 2 (Moderate intensity) : 3-4 bore/fruit

Scale 3 (High intensity) : 5-6 bore/fruit

Scale 4 (Very high intensity): $\geq$ 7 bore/fruit

4.6.3. Infestation Intensity and Yield Reduction

The yield of infested fruits corresponding to different scales of infestation intensity as shown in Table 6 display that the total weight of the infested fruits decreased very sharply with the increase of infestation intensity. For example, 33.57% reduced yield is observed under infestation intensity corresponding to Scale 4 followed by 18.44% reduced yield in case of Scale 3 while the yield reduction is very minimum in case of Scale 1 (13.27%) and in Scale 2 (17.58%). Thus the infestation intensity has got significant impact on the yield reduction.

It may be made further clear that the infestation intensity reflects its impact on yield not simply by reducing the gross yield significantly but also by extending the damage as shown in Figure 3. It is revealed from the Figure that total weight (yield) has drastically decreased, the proportion of damaged weight (yield) has sharply increased with the serious decrease in the healthy portion of fruit in case of higher Scales i.e., at higher infestation intensity. Thus at higher infestation intensity not only the yield was reduced drastically, but the consumable/edible yield also drastically reduced. Whereas, at lower infestation intensity, the gross yield as well us the proportion of consumable yield i.e., edible yield was not that seriously reduced and might be of significant worth both in terms of market value and home consumption

Thus from the above analysis it may be inferred that for proper evaluation of the effect of insecticide it would be logical to consider infestation intensity as a measure of comparison. The fruits under different treatments, therefore, should be sorted out into groups corresponding to different scales based on the number of bores per fruit. Otherwise, the results relating to efficacy of the insecticides in reducing the fruit infestation by brinjal shoot and fruit borer would be misleading failing to reflect the actual effect. Although not exactly the same,

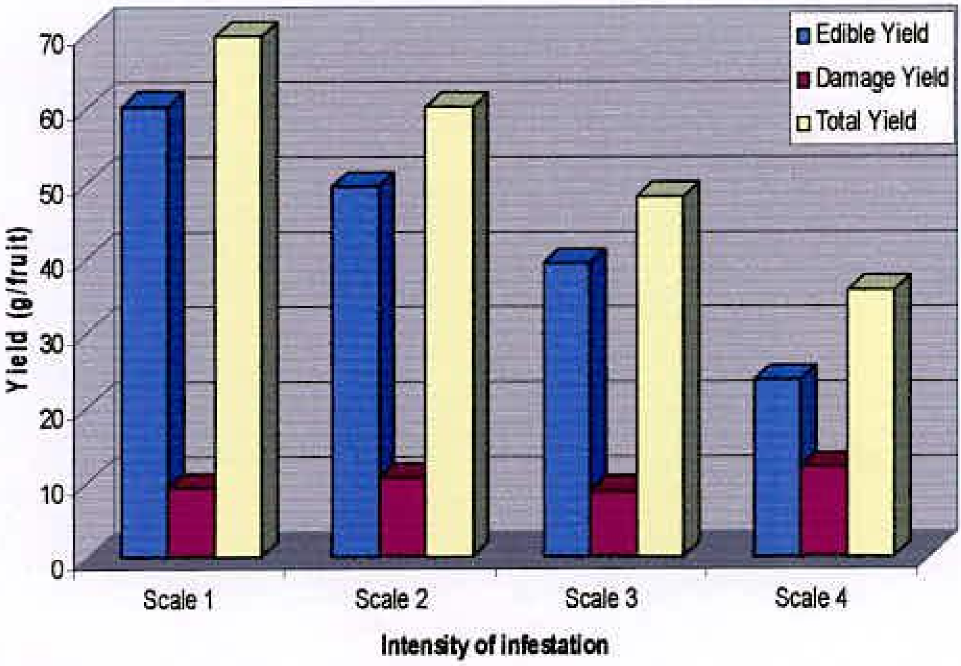

Figure 3. Relationship of intensity of infestation with edible, damage and total yield per fruit

similar approach had been followed in an experiment conducted by Biswas *et al.*(1998) who also observed significant difference in actual damage and consumable proportion of fruits in different varieties subject to a field screening against brinjal shoot and fruit borer.

4.7. Benefit / Cost Analysis

Benefit/cost ratio (BCR) of various control methods for the control of brinjal shoot and fruit borer are presented in Table 8. In this study untreated control (T_5) 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 8 that the adjusted net return was the highest (Tk. 206360.00) in T_3 (Marshal 20EC) followed by Tk. 153560.00 in T_4 (Chlorpyrifos 20EC), Tk. 118360.00 in T_2 (Ripcord 10EC) and Tk.81880.00 in T_1 (cymbush 10EC). Similarly, it is revealed that the BCR was the highest (21.33) in case of T_4 which was much higher than all other treatments having BCR <15.41 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 7. 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				
T_1	7320	14.72	4.72	351040	343720	81880	11.19
T_2	7680	16.61	4.64	387880	380200	118360	15.41
T_3	14400	23.5	1.05	482600	468200	206360	14.33
T_4	7200	19.9	2.05	422600	415400	153560	21.33
T_5	0	8.91	6.97	261840	261840	--	--

T_1= Application of Cymbush 10EC @ 500 ml/ha at 28 days after transplanting and repeated at 7days interval.
T_2 = Application of Ripcord 10 EC @ 500 ml/ha at 28 days after transplanting and repeated at 7days interval.
T_3 =Application of Marshal 20 EC @ 1500 ml/ha at 28 days after transplanting and repeated at 7days interval.
T_4 =Application of Chlorpyrifos 20 EC @ 1000 ml/ha at 28 days after transplanting and repeated at 7days interval.
T_5 = Untreated control.

Cost of insecticides:
Cymbush 10 EC @ Tk. 610/ha for single spray
Ripcord 10 EC @ Tk. 640/ha for single spray
Marshal 20 EC @ Tk. 1200/ha for single spray
Chlorpyrifos @ Tk. 600/ha for single spray

Market price of brinjal: Tk 20.00/kg for healthy and Tk. 12.00/kg for infested fruit

Chapter V

Summary and Conclusion

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SUMMARY AND CONCLUSION

An experiment was conducted at the Horticulture farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh during the period from December 2005 to June 2006 to evaluate the efficacy of four different insecticides for selecting the most effective one against brinjal shoot and fruit borer *(Leucinodes orbonalis* Guenee).

Marshal 20 EC applied at 28 days after transplanting and repeated at 7days interval (T_3) ensured significantly the highest reduction in shoot infestation (65.18%) over the control where the shoot infestation was the lowest (23.50%) in T_1 (Cymbush 10EC applied at 28 days after transplanting and repeated at 7days interval). This was followed by 34.82% and 44.60% shoot infestation in T_2 (Ripcord 10 EC applied at 28 days after transplanting and repeated at 7days interval) and in T_4 (Chlorpyrifos 20 EC at 28 days after transplanting and repeated at 7days interval) respectively. The T_3 also reduced the fruit infestation 3.15% (by number) 4.28% (by weight) respectively were observed. This was followed by 8.20% reduction in fruit infestation in case of T_4, and 21.06% in case of T_2 and 24.22% in case of T_1.

The total fruit yield was highest (24.55t/ha) in case of (T_3) followed by significantly lower yield (21.95 t/ha) in case of T_4, 21.25% t/ha in T_2 and 19.44 t/ha in T_1 having no significant difference with each other where 75.88 t/ha yield was in control. Thus the application of Cymbush 10EC was not enough to protect the fruit yield from the pest attack. On the other hand, T_3 ensured the maximum increase (163.75%) of healthy fruit yield followed by significantly less increase (123.34%) in T_4 and 86.42% in T_2, and 65.21% in T_1 having significant difference among themselves. The T_3 also ensured highest reduction (84.94%) in infested fruit yield while it was significantly lower in T_4 (70.59%)

followed by T_2 and T_1 having no significant difference among T_1 and T_2. 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 both T_4 and T_3 having no significant difference between them followed by 11.76% in both T_2 and T_1 as against 12.50% in control. The most significant finding is that considerably a very high proportion of infested fruits (50.00%) belonged to Scale 1 in T_3 followed by 44.44% in T_4, 47.06% in T_1 and 41.18% in T_2 against only 37.50% in control.

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 intensity i.e., in terms of number of bores per fruit. Therefore 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. The study also indicated that the infestation intensity has quite a significant effect on the size, extent of damage and weight of the fruit. The fruits belonging to Scale 4 differ quite significantly in size, damaged area, total weight, damaged weight and fresh weight from those belonging to Scale 1. Benefit/cost ratio (BCR) as worked out indicate that the adjusted net return was the maximum (Tk. 206360.00) in T_3 followed by Tk. 153560.00 in T_4 and Tk.118360.00 in T_2 and 81880.00 in T_1. But the BCR was the maximum (21.33) in case of T_4 which was much higher than that of all other treatments.

Among the treatments T_3 (Marshal 20 EC applied at 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 but BCR was highest in T_4. T_3 showed the highest increase (163.75%) of healthy fruit yield and highest reduction (95.38%) in infested fruit yield by number. Another significant finding is that considerably a very high proportion of infested fruits (50.00%) belonged to Scale 1 in T_3 as against only 37.50% in control. Among the infested fruits those belonging to Scale 4 were zero. Thus at higher infestation intensity not only the yield is reduced drastically, the edible yield also gets drastically reduced. Whereas, at lower infestation intensity, the gross yield as well as the proportion of consumable yield is not that seriously reduced. Therefore, infestation intensity should also be taken as a measure of efficacy evaluation.

Among the different insecticides Marshal 20EC (applied at 28 days after transplanting and repeated at 7 days interval) may be recommended for controlling the brinjal shoot and fruit borer.

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CHAPTER VI

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Appendices

Appendix I. Weekly record of air temperature, relative humidity and rainfall of the experimental site during the period from 7 March 2006 to 23 May 2006

Date	Air temperature (°c)		Relative humidity (%) at 9 a.m.	Rainfall (mm)
	Maximum	Minimum		
07/03/06	33.1	23.5	70	0
14/03/06	32.5	20.2	49	0
21/03/06	34.6	18.0	34	0
28/03/06	34.7	25.5	66	Trace
04/04/06	32.6	23.0	85	102
11/04/06	33.0	25.8	82	Trace
18/04/06	27.8	22.3	87	6
25/04/06	35.0	21.0	50	0
02/05/06	34.8	26.6	67	0
09/05/06	34.4	26.2	75	02
16/05/06	34.7	25.8	63	0
23/05/06	34.3	26.7	64	2

Source: Bangladesh Meteorological Department (Climate Division), Agargoan, Dhaka-1212.

Appendix II. Characteristics of Horticulture Farm soil is analyzed by Soil Resources Development Institute (SRDI), Khamar Bari, Farmgate, Dhaka.

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Horticulture Garden ,SAU, Dhaka
AEZ	Madhupur 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	Fellow – lettuce

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: SRDI