SCREENING OF SOME LOCAL AND IMPROVED BRINJAL (*Solanum melongena*) GENOTYPES AGAINST BRINJAL SHOOT AND FRUIT BORER (*Lucinodes orbonalis* Guenee) VIA FIELD TRIAL AND BIOCHEMICAL ASSAYS

A THESIS

BY

Sumaiya Ferdousi

STUDENT ID: MS-200810

MASTER OF SCIENCE (MS)

IN

HORTICULTURE

AGROTECHNOLOGY DISCIPLINE

LIFE SCIENCE SCHOOL

KHULNA UNIVERSITY

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A Thesis (Course No. HRT-6104) Submitted to the Agrotechnology Discipline in Partial Fulfillment of the Requirements for the Degree of Master of Science in Horticulture (MS)

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Student Id: MS-200810

Approved as to style and content

By

31.07.22

Professor Dr. Md. Abdul Mannan

(Supervisor)

Professor Dr. Shimul Das

(Co-Supervisor)

Professor Dr. Sarder Safiqul Islam

(Chairman, Examination Committee and

Head, Agrotechnology Discipline)

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Abstract

Brinjal shoot and fruit borer (BSFB), *Leucinodes orbonalis* Guenee, is a devastating pest of brinjal (*Solanum melongena* L.) in all brinjal growing countries across the globe. To ecofriendly manage the pest, the study aimed at isolating some promising brinjal genotypes offering moderate to high resistance to brinjal shoot and borer infestation (BSFB). To achieve the objectives, a total of 10 brinjal genotypes were filed in experimental plots of Germplasm center of Khulna University, Bangladesh during September 2020 to May, 2021 following single factor randomized complete block design (RCBD) with three replicates. The statistical analysis revealed that brinjal genotypes of BARI BT begun-4 only conferred higher resistance to BSFB infestation implying it had reduced shoot and fruit infestation. In contrast, rest of the genotypes came up with susceptibility to BSFB. In term of volume index, BARI hybrid Begun 4 performed better than others while shape index was higher in Local cultivar 2. BARI Hybrid Begun 4 had greater mesocarp and pericarp thickness although it was not resistant. The findings unveiled that BARI BT Begun-4 could potentially be used in ecofriendly combat of BSFB infestation without any pest management cost although its productivity and fruit quality attributes are much lower than BARI hybrid Begun 4 which necessitates a variety of pest management tactics. Further economic study is required to explore the real life effectiveness of BARI BT Begun-4 over BARI hybrid Begun-4 for widespread cultivation.

Keywords: BSFB infestation, brinjal genotypes, resistant varieties, resistant.

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CHAPTER 1

INTRODUCTION

Brinjal also known as eggplant belonging to the family "*Solanaceae*" is normally a self-pollinated annual crop. It is an important native crop of tropical and subtropical zones of the world. The global production of eggplant is around 55.2 million tons annually, which makes it the third most economically important Solanaceous vegetable after potato and tomato and 94.2% of total production is produced in Asia (Taylo et al., 2016). The top three brinjal producing countries are China (35.55 million tons; 64.4% of the world's total), India (12.68 million tons; 23% of the world's total), Egypt (1.18 million tons) (FAO, 2019).

In Bangladesh brinjal is one of the most popular and favored vegetables. Though the crop is grown throughout the country, it is commercially cultivated in Jessore, Rajshahi, Narsinghdi, Dhaka, Cumilla, and Bogura districts. It is grown in both Rabi and Kharif seasons in Bangladesh. In 2018-19, Rabi brinjal has been cultivated over 33198.4 ha of land and the total production was 360000 Tons and Kharif brinjal has been cultivated over 19028.4 ha of land and the total production was 170000 Tons (BBS, 2020).

Regarding nutritional value, brinjal possesses a very low caloric value but high content of vitamins, minerals, and bioactive compounds for human health (Raigón et al., 2008; Plazas et al., 2014b; Docimo et al., 2016). Nutrients and their contents in Brinjal include energy (1%) 100-104 kJ, carbohydrates (4%) 4.70- 5.88 g, protein (2%) 0.80 - 1.01 g, Fat 0.18-0.20g P 22.5 - 25 mg, Sugars 2.35-3.53 g, Dietary fiber (9%) 2.80-3.40g and other vitamins and minerals (Naeem and Ugur, 2019). Brinjal is quite susceptible to several environmental stresses, especially acute temperature, drought, salinity, and inadequate moisture stresses (Toppino et al., 2021) which affect the growth and development of the plant. It has a relatively longer growth period and life span. Brinjal is more vulnerable to a broad range of plant diseases, pests, nematodes, and weeds than other vegetable crops. The major handicap to the sustainable productivity of brinjal in Bangladesh is the high incidence of insect pests. In total 9 species of insects belonging to 7 families of 4 orders have been reported as major pests in brinjal field e.g. Epilachna beetle (*Epilachna dodecastigma*), Jassid (*Amrasca biguttula*), Whitefly (*Bemisia tabaci*), Shoot and fruit borer (*Leucinodes orbonalis*), Aphid (*Aphis gossypii*), Thrips (*Thrips hawaiiensis*) and Leaf hopper (*Amrasca devastans*) (Amin et al., 2018). Among them, Brinjal Shoot and Fruit Borer (BSFB) is reported as key pest that can inflict about 16 % and 70% damage to shoots and fruits, respectively (Kar et al., 2020). BSFB scales down the productivity as well as the quality of marketable fruits of brinjal. The larval stage of the pest is mainly catastrophic and can cause severe damage to fruits and shoots. Newly hatched larvae invade the vascular bundle of the plant and hit translocation of food and nutrients towards shoots. Approximately 4-6 healthy fruits can be destroyed because of the attack of a single larvae (Jayaraj and Manisegaran, 2010). Due to its concealed mode of life, the pest is very difficult to control by using synthetic pesticides only (Sardana et al., 2004). This insect pest is accountable for 70-92% of yield loss (Chakraborti and Sarkar, 2011). There are several measures to mitigate this destruction including spraying of chemical insecticides, application of botanical pesticides, adopting IPM technologies, using resistant varieties and so on. It is a matter of sorrow that to control this detrimental pest, farmers are spraying pesticides indiscriminately. They are not following the recommendation guidelines as well. A survey report revealed that 98% of Bangladeshi farmers are dependent entirely on spraying insecticides to control BFSB (Karim, 2004). Now a days it is the burning question to ensure eco-friendly pest management under IPM technology using safe eco-efficient method involving the use of resistant genotypes. In Bangladesh, especially south western region there is very sketchy scientific evidence on screening of brinjal genotypes against BSFB. Therefore, the present research has been undertaken to identify the resistant varieties of brinjal for ecofriendly management of BSFB. The specific objectives of the study are as follows:

- To compare the selected brinjal genotypes based on yield and fruit quality attributes.
- To determine the BSFB infestation in tested brinjal genotypes and rank them accordingly.
- To characterize the brinjal genotypes offering tolerance or resistance to BSFB.

CHAPTER 2

REVIEW OF LITERATURE

Brinjal, *Solanum melongena L.* is one of the most common and popular vegetable crops in Bangladesh. It is grown across Bangladesh round the year. Brinjal is a warm season crop requires continuous long warm weather during growth and fruit maturation. The optimum growing temperature is 22-30ºC and growth stops at temperature below 17ºC (Toppino et al., 2021). Brinjal is self-pollinated annual crop. Its cultivation helps to improve human nutrition and income generation. Various factors are responsible for low yield of Brinjal in Bangladesh and out of which attack of different pests is one of the most important one. The brinjal is attacked by as many as 53 species of insect pests (Abhishek and Dwivedi, 2021). Of these, brinjal shoot and fruit borer (BSFB), Leucinodes orbonalis Guenee, is the most serious one causing significant damage to crop.

BSFB is a phytophagous insect and belongs to the order Lepidoptera and family Pyralidae. This pest is active throughout the year at places having moderate climate but its activity adversely affected by severe cold. This pest is not common in temperate region. The incidence of this pest occurs sporadically or in epidemic form every year throughout Bangladesh and affecting adversely the quality and yield of the crop. The damage caused by brinjal shoot and fruit borer varies from 12-16% for shoot and 20-63% for fruit (Kar et al., 2020).

To control this notorious pest, only two approaches are being used in Bangladesh. One approach advocates clean cultivation with hand picking of eggs, infested shoots and fruits. The other approach is to apply insecticides at an interval of 10-15 days. Use of resistant variety is another method of pest management. Varietal resistance and tolerance acts as preventive method of bio-control. This technique can be used against the Brinjal shoot and fruit borer to keep its population below economic injury level (EIL).

Resistance, tolerance or susceptibility of brinjal plants to brinjal shoot and fruit borer involve a great cause and effect relationship between the insects response to the plant and in turn the plant's reactions to the insect pest. These responses are behavioral like orientation, feeding, oviposition and physiological, such as metabolic utilization of ingested food, growth, survival, egg production and hatching. The capacity of a plant to cause the interruption of any of these may account for its resistance to brinjal shoot and fruit borer infestation (Kar et al., 2020).

An effort has been attempted to present a brief review of research in relation to varietal performance of brinjal against brinjal shoot and fruit borer. In Bangladesh limited work of varietal performance of brinjal has been done. A brief review of the literature available in Bangladesh and elsewhere related to varietal performance of Brinjal against Brinjal shoot and fruit borer is discussed below:

2.1 **General features of Brinjal Shoot and Fruit Borer, L. orbonalis**

2.1.1 Nomenclature

Brinjal shoot and fruit borer (BSFB) was first described *as Leucinodes orbonalis* by Guenee in 1854. It was designated as the type species of the genus by Walker in 1859. The genus includes three species, *L. orbonalis Guenee, L. diaphana I lampsn and L. apicalis I lampson* (Gautam et al., 2019).

Taxonomic position

Phylum: Arthropoda

Sub-phylum: Mandibulata

Class: Insecta

Order: Lepidoptera

Family: Pyralidae

Genus: *Leucinodes*

Species: *Leucinodes orbonalis*

2.1.2 Host range

Shoot and fruit borer is the most destructive pest of Brinjal. It was also found to attack shoots and fruits of tomato, potato (*Solarium tuberosum L.),* green peas (*Pisum sativum L.*) and *Solanum torvum Swartz* (Alam et al., 2006). Other wild species of *Solanum* are also attacked by this pest. .

It has been reported that several alternative host including *Solanum tuberosum, S. lycopersicum, S. nigrum, S. indicum, S. torvum, S. myriacanthum,* potato and other solanaceous crops. (Dash, 2020). The insect was found to be able to complete its development on tomato and also on the weed *S. nigrum*, but moths that had been reared on the latter were smaller and laid fewer eggs than those reared on tomato or brinjal.

2.1.3 Origin and distribution

Leucinodes orbonalis is native to India but occurs in the Indian Sub-continent (Andaman Island, India, Pakistan, Nepal, Bangladesh and Sri Lanka), Far-East Asia (Hong Kong, China, Taiwan and Japan), Africa (Burundi, Cameroon, Congo, Ethiopia, Ghana, Kenya, Lesotho, Malawi, South Africa, etc (Kumar, 2009). Brinjals are severely attacked by shoot and fruit borer in the tropics but not in the temperate zone (Kar, et al., 2021).

2.1.4 Nature of damage

The damage by this pest starts soon after transplanting of the crop and continues up to 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. In young plants, 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 (Abhishek and Dwivedi, 2021).

The infested shoots droop due to disruption of vascular system and ultimately wither (Alam et al., 2006) and the borer continues boring the stem until it encases itself. At the later stage of plant growth, when the flower-bud comes out the larvae at first bore generally through the calyx and later into the flower buds and the fruits without leaving any visible sign of infestation and feed inside (Abhishek and Dwivedi, 2021).

The infested flowering buds dry and shed. Infested fruits show exit holes along with excreta. The caterpillar rests in a cell of fruit. The affected fruit, when cut open is sometimes found rotting with full of dark excreta. Moulds grow there in and thus make the fruit unfit for human consumption and marketing. The full- grown larvae came out through the hole of the infested fruits and drop on the ground for pupation in the soil or plant debris. The infestation of fruits is more than that of the shoots (Alam et al., 2006).

2.1.5 Seasonal abundance of BSFB

The seasonal history of 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. They are less active during February to April (Yousafi et al., 2016).

A study revealed that the population of this insect began to increase from the first week of July and peaked (50 larvae per 2m) during the third week of August. The population to this pest was positively correlated with average temperature, mean relative humidity and total rainfall (Hossain and Hossain, 2016). During winter months, the duration of different stages last for longer periods. Overlapping of generations was observed. 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. During summer months, each generation covers about four to six weeks but in winter months it covers up to the extent of sixteen weeks .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 (Kumar et al., 2009)

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 (Alam et al., 2006). Populations of Leucinodes orbonalis on eggplant increased in the 1st and 3rd and declined in the 2nd and 4th generations.

Patel et al. (2008) observed low population variation in minimum and maximum temperature but high relative humidity and heavy rain enhanced the population of this pest. In another study Mohanraj et al. (2005) reported that 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 the 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.

2.1.6 Life history

Egg:

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 continue till the early hours in the morning (Ghosh et al. 2009). The number of eggs laid by an average female varies from 80-253. According to (Shukla et al. 2010) the average number of eggs laid per female was 121.5 ± 0.449 and of these 79.24% were viable. The egg measures on an average 0.44 mm × 0.32 mm with creamy white color and changed into yellow to yellowish orange as the development proceeds.

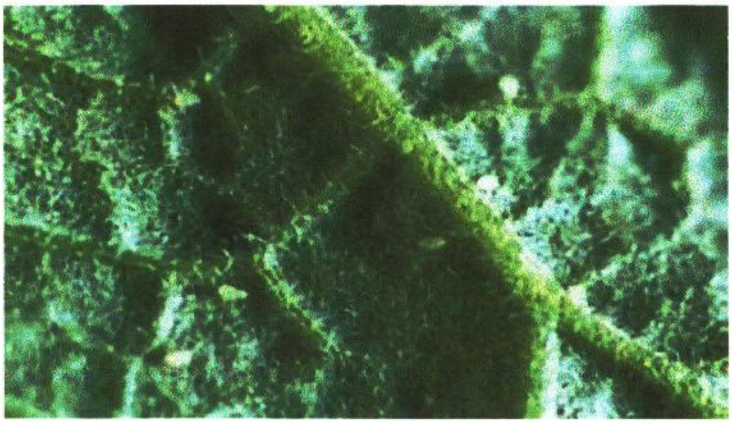


Plate-1. Egg of BSFB

Larvae:

The young larva on hatching measures 1.49 mm × 0.41 mm with slender abdomen tapers posterior. It is dull white color with yellowish tinge which later turns into creamy white. The full-fed larva measures 16.3 mm × 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 than those of the rest (Alam et al., 2003). Shukla et al. (2010) observed that *Leucinodes orbonalis* 1st instar larvae occurred in flower buds and flowers, while 2nd instars larvae were present in all susceptible parts of the plant. Larvae were confined to the shoots and fruits in their 3rd and 4th instars, while 5th instars 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 instars. Larval stage lasted for 21.2-12 days.

Plate-2. Larvae of BSFB

Pupae:

The pupa is formed within a boat shaped cocoon of dirty brown coloured silk which is spun by the full grown larvae before pupation in a suitable dark or semi-dark place in soil and plant debris. During rainy season pupation takes place on the stems or shoots or the dried leaves of the plants (Alam et al., 2003). The full grown pupa measures 6.4 mm × 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. The incubation, larval and pupal periods are 3 to 5, 12 to 15 and 7 to 10 days during the summer and 7-8, 14-22 and 13-15 days in the winter, respectively. One to six generations were completed annually over-wintering as pupae (Ghosh et al., 2009).

Plate-3. Pupae of BSFB

Adult

The adult *Leucinodes orbonalis Guenee* moths are white and cryptic in nature with 22 to 26 mm long at wing expanse (Alam et al., 2003). 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. The margins of both the wings are 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 (Ghosh et al., 2009).

The life cycle is completed in 34 to 59 days with five or more overlapping generations per year. The insects are active throughout the year with more activity in the summer and rainy season than in the winter months (Alam et al., 2003). Adults were not active during the day, copulation and oviposition take place at night.

Another study revealed that the egg stage averaged 5.4 days, the larval stage 17.5 days, the pupal stage 9.8 days, the pre-oviposition and oviposition periods 1.2-2.1 and 1.4-2.9 days, respectively, and adult male and female life-span 1.5-2.4 and 2.0-3.9 days respectively. Average fecundity (eggs/female) ranged from 84.5 in January to 253.5 in May (Hanson et al., 2006).

Plate-4. Adult BSFB

2.2. Management of brinjal shoot and fruit borer

2.2.1 Cultural practices

Cultural control is the deliberate manipulation of the environment to make it less favorable for the pest by disrupting the reproductive cycle, eliminating their foods or by making it more favorable for their natural enemies. The cultural techniques of pest management help to improve the plant condition in many ways. Cultural methods like clean cultivation, destroying crop residues and alternate host, use of balanced fertilizer, shifting of planting or harvesting time, crop rotation, etc. are known to be useful for the management of brinjal shoot and fruit borer infestation (Talekar, 2002).

Ghimire and Khatiwada (2001) reported that cultural methods, like crop rotation and intercropping manipulate the environment to make it less favorable to pests. However, no significant result was obtained for reduction of infestation by intercropping with corn or stringbeans.

The cultural practice, i.e., pruning of infested twigs and branches prevents the dissemination of L. orbonalis. Similarly, the periodic pinching/pruning of wilted damaged shoot, their collection and burying or burning helps to reduce pest infestation (Neupane, 2000).

2.2.2 Mechanical practices (clipping of infested plant parts).

Removals of infested shoots and fruits along with the larvae and destroying them mechanically may help in reducing BSFB population in the field. Mechanical elimination of infested shoots and fruits could be an effective IPM technique. This technique when complemented with spray of chemical insecticides gave satisfactory result as compared with sprays of chemical insecticides alone (Dutta et al., 2011).

The moth is not a good flyer, only flies short distances from one plant to another or from one plot to the next. So, eggplant can be protected by preventing adults by erecting suitable nylon net barrier at suitable heights (NARC, 2000). The use of barriers combined with prompt destruction of the pest significantly reduced the damage than any single methods (Alam et al., 2003).

The highest marketable fruit yield and as well as lowest fruit infestation for number and weight was obtained from use of barrier + clipping practices followed by the use of barrier alone but it is best for farmers practice in small scale production, especially for off-season production (Ghimire, 2001).

2.2.3 Bio-pesticides and other bio-control agents:

Bio-pesticides have high compatibility with other pest management techniques, such as natural enemies, resistant varieties, etc. Therefore, it could play a vital role in IPM strategies although they cover only about 4 percent of the global pesticide market (Srinivasan, 2012). They have minimal effect on non-target organisms. Similarly, the potential human health effects are not known so far. The combination of plant products and synthetic microbial pesticides are reported to possess insect controlling properties. These insecticides can provide environmentally safe product for biological management of this pest. Among the bacteria, the spore forming species, *Bacillus* spp. have been most important in insect suppression. Different commercial products of Bt are available on market and the efficacy also vary according to place and product type.

Saimandir and Gopal (2012) showed that Biolep was not effective; however, PUSA Bt gave better control against *L. orbonalis* at similar dose. Chatterjee and Mondal (2012) reported that *Bacillus thuringiensis* (Berliner) performed well in reducing damage and increasing yield. Bt formulation Biolep was found to be effective than synthetic insecticide (Sharma, 2002) and efficacy increased in successive days of spray (Mainali et al., 2012). Although numerous predators and parasitoids are identified as bio-control agents of many insect pests but only few have been found to control BSFB. So far little success has been achieved for the management of BSFB using these natural 17 enemies. . (Chatterjee and Mondal, 2012) observed that after hatching from eggs, the parasitoid maggot feeds on the endocarp of the fruits and secrete an offensive smelling fluid which probably makes the fruit borer rotten. This secretion affects the growth of the larvae and as a result, the larva shrinks and ultimately dies. The mortality of adult moths occurred by the attack of predatory black ant, *Camponotus compressus* Fb. and excessive rainfall during summer. The 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 (Ghimire, 2001).

A pupal parasitoid, *Itamoplex* sp. was reported from Kulu Valley, Himachal Pradesh, India where the winter temperature drops as low as – 8 ºC. The parasitoid emerged from 9-15% of the larval cocoon of BSFB. *Itamoplex (Cruptus)* sp. was also recorded attacking a range of Lepidopteranian cocoon (Chatterjee and Mondal, 2012).

Mainali, 2012 reported that 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%. *Trathala flavo-orbitalis* is recorded from *L. orbonalis* in India and also in Sri Lanka where L. *orbonalis* is its major host and where an average parasitization level of 36.2% 18 has been reported.

2.2.4 Use of botanical pesticides

It has been found that there are many plant species available throughout the tropics so far having some kind of pesticidal properties. According to (Prakash et al., 2008) eco-friendly, less costly measures, such as, cropping system approach, botanicals are more advantageous over insecticides, as they fit well in IPM. The safer plant products are useful in developing sound pest management strategies (Gupta and Singh, 2002).

Azadirachtin containing extracts from neem seeds have anti-feedant and sterilent properties. It was found that azadirachtin also act as a chitin synthesis inhibitor which control over the neuroendocrine system, ecdysone and juvenile hormone synthesis. However, the result regarding use of azadirachtin based pesticides on management of *L. orbonalis* vary greatly. In the same experiment (Saimandir and Gopal, 2012) reported that NSKE was effective, however NimboBas non-effective. Muregesam and Murugesh, (2009) proved the effectiveness of Nimbecidine. The product Neem cake extract @ 5 percent and *Calotropis gigantean* (Linnaeus) @ 5 percent were also quite effective in Kharif crop reducing fruit damage by more than 50 percent.

The oil product of botanicals was found to be efficient for *L. orbonalis* management. Neem oil @ 2 percent was the best treatment both in Kharif (60.20%) and Rabi (59.91%) followed by Nimbecidine @ 2 ml/litre (57.42%) (Murugesam and Murugesh, 2009). Several earlier workers have also demonstrated the effectiveness of Neem oil against *L. orbonalis.* Similarly, (Mathur et al.2012) showed that 2 percent of newer botanical oils of Pungam (*Pongamia pinnata* Linnaeus) and Iluppai (*Madhuca indica* Gmelin) in IPM modules proved to be quite effective in lowering both shoot and fruit infestation and can thus be utilized in resistance management strategy.

Experiment with botanical pesticides has also been conducted in Bangladesh on a limited scale. All the botanicals, such as Ecogold @ 10 ml/litre of water; Alata soap @ 5 g/litre of water; Garlic @ 30 g/litre of water; Neem oil @ 3 ml/l of water); Papaya leaves @ 92 g/litre of water and Wood ash @ 10 g/plant significantly reduced the different pest of eggplant including *L. orbonalis.* Therefore, it is considered as pest management options to reduce insect pest populations and increase eggplant productivity (Mochiah et al., 2011). Field trail with neem products have shown, not only a decrease in damage by pest but also an increase in crop yield compared to those obtained with recommended synthetic insecticides. A methanol suspension of 2-4% of the neem leaves have been used against the caterpillar of diamondback moth, Plutella xylostella and it was as effective as either synthetic insecticides mevinphous (0.05%) or deltamethrin in (0.02%) in Togo (Mathur et al., 2012).

2.2.5 Chemical method

Chemical insecticides are the most powerful tools available for the management of insect pests. Insecticides are highly effective, rapid in curative action, adaptable to most situations and relatively economically. Insecticide is the only tool for pest management, which is reliable for emergency action when insect pest populations approach or exceed the economic threshold level. Since no other dependable control measure of the pest is available, chemical control measure has remained as the key for the control of this pest. Wide ranges of insecticides (Organophosphorus, Carbamates and Synthetic Pyrcthroids) and varying spray formulations have been advocated from time to time against the BSFB (Karim, 2004).

Recent scientific research found that Chlorantraniliprole 9.3% + Lambda Cyhalothrin 4.6% ZC pesticides proved their highest efficacy against BSFB (Goud et al., 2019). Ampligo 150 ZC is a new ready mix formulation (Chlorantraniliprole 9.3% + Lambda Cyhalothrin 4.6% ZC) reported as an effective chemical insecticide against *Leucinodes orbonalis.* The lowest percent of the shoot (1.26%) and fruit (2.49%) infestation was recorded by applying Ampligo 150 ZC @ 28 g a.i./ha. The highest marketable fruit yield was recorded 143.91-150.88 q/ha. It is proved to be significantly superior to other treatments against BSFB (Sen et al., 2017). A field study revealed that the most effective combination of 3 pesticides i.e. Chlorantraniliprole 9.3% + lambda-Cyhalothrin 4.7% @ 200 ml/ha or 28 g a.i./ha and gave maximum fruit yield and maximum increase in yield against BSFB. No phyto-toxicity to the plant was observed due to applying the combination doses (Singh et al., 2015).

A three year study was carricd out at Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, Bangladesh to evaluate the efficacy of some insecticides to control the BSFB L. orbonalis G., Carbofuran 3G @ 30 kg/ha showed the highest level of efficacy. Among the other treatments Cypermethrin 10EC was found to be effective against the pest (Akter et al., 2018).

Dey (2019) reported that Cartap Hydrochloride combined with Emamectin Benzoate can be most effective against BSFB. The combination of these two pesticides can be recommended for safe and economic use in brinjal for effective control of shoot and fruit borer. Another study revealed that Cartap hydrochloride showed an effective result in minimizing shoot infestation (0.05%) just after Chlorantraniliprole (0.002%) and Emamectin Benzoate (0.002%). It is recognized that the next effective treatments are Emamectin Benzoate (8.09%) followed by Cartap hydrochloride (8.84%) (Khanzada et al., 2018).

Cypermethrin is one of the most effective pesticides to Control BSFB. In a recent study, a minimum percent of shoot infestation (11.67%), fruit infestation (13.39%), and Benefit-Cost ratio (1:11.15) have been recorded in Cypermethrin application (Yadav and Tayde, 2018). Researchers found that the highest mean number of healthy shoots (112.23 shoots/plot), maximum number of healthy fruits (30.73 Kg/plot), and minimum percent fruit infestation (8.97%) was recorded by applying Cypermethrin combined with *Trichogramma chilonis*. Again individually Cypermethrin showed similar results including 109.3 health shoots/plot, 22.42 Kg healthy fruits/plot (Murali et al., 2017).

2.2.6 Varietal resistance

Shaukat et al. (2018) tested some morphological characteristics which lower the attack of the BSFB. They estimated that increase in the number of shoots per plant will lower the attack of the pest. It is also examined that round shape fruits are more susceptible compared to long shaped fruits. They investigated some physical and chemical feathers ,for example plant structure, fruit form, spines of leaves, fruit skin thickness, branches, petioles, calyx of fruits, chemical traits viz., ash, crude fibre, silica, total phenol contents towards the shoot and fruit borer resistance in brinjal.

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

Ahmed et al. (2008) evaluated twenty brinjal varieties/lines to identify their characteristics for susceptibility/resistance against brinjal shoot and fruit borer infestation. In case of shoot infestation, the varieties/lines Katabegun WS, and Marich begun S were found to be tolerant while the varieties/lines Amjuri, Borka, Dharola, Deembegun, ISD 006, Kajla, Khatkhatia BAU, Laffa S, Singnath, Thamba and Uttara were found to be moderately tolerant; BL-118, Eye red, Islampuri BADC, Irribegun and Nayantara were found to be susceptible; Bijoy and Kaikka N were found to be highly susceptible. In case of fruit infestation, the varieties/lines Thamba and Katabegun WS were found to be tolerant while the varieties/lines Amjuri, BL-118, ISD 006, Islampuri BADC, Irribegun, Marich begun S, Kajla, Khatkhatia BAU, Laffa S and Singnath were found to be moderately tolerant; Borka, Dharola, Deembegun, Eye red, Kaikka N, Nayantara and Uttara were found to be susceptible and the variety Bijoy was found to be highly susceptible.

Rishi et al. (2018) observed 40 germplasm of brinjal for their reaction against shoot and fruit borer. They observed minimum infestation on germplasm HMB-10 which is 14.18%. maximum infestation of 53.19% was noticed on H-129. It was observed that shape index has significant negative association with fruity infestation, whereas thickness of mesocarp was positively significantly correlated.

Thirteen Solanum spp. genotypes and 30 F1 crosses of S. melongena were evaluated for resistance to L. orbonalis during February – October, 2000 under field conditions in Palampur, Himachal Pradesh, India. Arka Keshva was found resistant to the pest. Four genotypes and 11 F1 crosses were also found resistant to fruit infestation, recording 2.75-10.00% fruit damage. Six lines, Pusa Anupam, Punjab Barsati, SM 6- 7, SM-141, CHES-243 and DBL V-4, with 17 F1 crosses were identified as fairly resistant. It was observed that attack of L. orbonalis was comparatively less fruits with tightly arranged seeds in the mesocarp (Amin et al., 2014).

Lalita et al. (2020) reviewed the host plant resistant approaches by use of resistant varieties to reduce the incidence of brinjal shoot and fruit borer to achieve sustainability in brinjal production technology. They investigated host plant resistant approaches by use of resistant varieties to reduce the incidence of brinjal shoot and fruit borer to achieve sustainability in brinjal production technology.

Prodhan et al. (2009) evaluated moisture content of brinjal shoot and fruit of twenty different varieties/lines was estimated to find out the relationship between the infestation rate of brinjal shoot and fruit borer, *L. orbonalis* Guenee and the moisture content of brinjal shoot and fruit. The highest level of shoot moisture (91.97%) and fruit moisture (95.89%) Were recorded in the line BLO 72 and the lowest level of shoot moisture (81.65%) and Fruit moisture (89.88%) in the variety Brinjal. Brinjal 16 shoot infestation was found to be positively correlated with shoot moisture (0.701) and fruit infestation was also positively correlated with fruit moisture (0.695).

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

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

Javed et al. (2009) screened different levels of infestation in aubergine cultivars by brinjal shoot and fruit borer. They observed maximum fruit infestation in cultivar Naeelam (58.60 and 48.09%) followed by black long (47.93 and 33.31%), while minimum was observed in Nirala with 24.75 and 21.57% fruit infestation. They found negative significant correlation between fruit infestation and plant height ($r = -0.716$), crown hair density ($r = -0.672$) while the correlations of leaf hair density ($r = -0.623$), and leaf area ($r = -0.613$), was also significant and negative but not so strong.

There was positive correlation with fruit yield (q/acre) and positive and non-significant correlation with number of primary branches/plant with r-value 0.661and 0.319, respectively.

A field trail was screened to evaluate Brinjal *(Solanum spp.)* germplasm against shoot and fruit borer, *L. orbonalis Guen*. Fifty four Brinjal (aubergine) germplasm, including five wild species and some F1 crosses were screened for resistance to *L. orbonalis*, during 1999-2000, under field conditions in Bhubaneswar, Orissa, India. None of the cultivated or wild species of Brinjal was found resistant to this pest. Three wild species, i.e. *S. khasianum, S. viarum* and *S. incanum*, were found to be tolerant from fruit infestation (0.5-10.0%). Among the cultivated lines, CHB-103, 187 and 259 were identified as fairly tolerant. Among the Brinjal groups, it was observed that in 19 genotypes with relatively long fruits and tightly arranged seeds, the attack of *L. orbonalis* was less. (Sridhar et al., 2001).

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

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

CHAPTER 3

MATERIALS AND METHODS

The present study of varietal performance of brinjal against brinjal shoot and fruit borer was carried out using 10 varieties of brinjal during September 2020 to May 2021. The materials and methods adopted in the study are discussed under the following sub-headings:

3.1 Experimental site

The study was carried out at the experimental field of the Germplasm Centre of Khulna University, Khulna, Bangladesh during September 2020 to May, 2021. The study area is situated at 24.09° North latitude and 90.26° East Longitudes with an elevation of 8.4 meter from the sea level.

3.2 Soil

The area belongs to the Ganges flood plain (AEZ-13), clay loam in texture having low organic matter (1.12%) moderately slow permeability and deficient in nitrogen, potassium and Sulphur in comparison with the standard nutrient status. The soil is mostly alkaline and somewhat saline in nature having pH between 6.5 to 8.5.

3.3 Climate

The climatic condition of Khulna University has unimodal rainfall pattern; most of the rainfall occurs during the months of May to September. The average rainfall is usually higher than 200 mm during November to March. The warmer months are April, May and June with mean maximum temperature of 31-34°c and the cold months are November, December and January when the temperature ranges from 10-19°C.

3.4 Land preparation and layout

The experimental land was first opened with a power tiller. Ploughed soil was then brought into desirable final tilt by four operations of ploughing followed by laddering. The stubbles of the crops and uprooted weeds were removed from the field and the land was properly leveled. The field layout was done on accordance to the design, immediately after land preparation. The good tilth main field was then divided into three main blocks considering 1 m block to block distance. Each block was sub-divided into 10 sub-plots for 10 brinjal varieties. The plots were then raised by 10 cm from the soil surface keeping the drain around the plots.

3.5 Manures, fertilizer and their methods of application

The experimental plots were fertilized as recommended by (Azad et al., 2020) for brinjal cultivation @ 15 tons of cow dung and 250, 150 and 125 kg of Urea, TSP and MoP respectively per hectare. The entire amounts of cow dung were applied at first land preparation. TSP, half of Urea and MoP were applied at the time of final land preparation. The remaining half of the Urea and MoP were applied at two equal installments as top dressing. The first top dressing was done 21 days after transplanting and second at the flowering stage of Brinjal.

3.6 Brinjal varieties used in the study

Ten brinjal varieties were used as study materials among them six varieties are developed and released by Bangladesh Agricultural Research Institute (BARI) and other four varieties were collected from local market and farmers. Ten brinjal varieties viz. BARI Hybrid Begun-2, BARI Hybrid Begun-4, BARI BT Begun-4, BARI Begun-9 and BARI Begun-10, Local Cultivar-1, Local Cultivar-2, Local Cultivar-3, and Local Cultivar-4 and BARI Begun-4 were used in the study.

3.7 Experimental layout and design

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The experimental area was divided into three equal blocks. Each block was divided into 10 plots, where 10 treatment combinations were allocated at random. There were 30 unit plots altogether in the experiment. The size of the each unit plot was 3.0 m × 2.5 m. The distance maintained between two blocks and two plots were 1.0 m and 0.5 m, respectively.

3.8 Seedling raising and transplanting

Standard seedling raising practice was followed (Amin et al., 2014). Thirty-six day-old (3/4 leaf stage) healthy seedlings were transplanted in 60 cm apart in 3.0 × 2.5 m size plots in rows laid out in RCBD design with 3 replications. Each row separated by 50 cm represented a replication and contained 16 plants of each variety. After transplanting light irrigation was given to each pit. Dead or damaged seedlings were replaced immediately by new ones from the stock. Supplementary irrigation was applied at an interval of 2-3 days.

Plate-5. Experimental plots of brinjal

3.9 Intercultural operations

After transplanting of seedlings, various intercultural operations were accomplished for better growth and development of the plants. When the brinjal seedlings were well established, the soil around the base of each seedling was pulverized. A few gaps filling was done by healthy seedlings of the same stock where initially planted seedlings failed to survive. Weeding and mulching were accomplished as and whenever necessary to keep the crop free from weeds, for better soil aeration and to break the crust. It also helped in soil moisture conservation. Propping of each plant using bamboo sticks (l m height) was done for providing extra support to avoid lodging of the plants.Irrigations were given throughout the growing period at 10-15 days interval. The irrigations were given to increase the yield.

3.10 Data collection

3.10.1 Infestation level

The incidence of *Leucinodes orbonalis* Guenee. was recorded at seven days intervals starting from the first appearance of shoot and fruit borer after transplanting the brinjal crop and continued till the harvesting of the crop. The infestation and intensity of *Leucinodes orbonalis* Guenee on young plants were recorded by counting infected and healthy shoots on randomly counted at each picking (weekly). Damaged (%) on shoot and fruit was calculated by recording the number of total and infested shoot and fruit.

The observation was converted into percentage and germplasm were classified according to the scoring pattern adopted. The germplasm was categorized as Highly Resistance (%), Resistant (0-15%), Moderately Resistant (16-30%), Susceptible (31-45%) and Highly Susceptible (above 46%) respectively. (Subbratnam and Butani, 1981).

Total number of infested shoots and fruits due to the infestation by the natural population of BSFB from randomly selected 5 plants /replication were counted and recorded at every 14 days interval from 30 DAT. Data on brinjal plant and fruit characters for each of the following parameters were recorded.

3.10.2 Plant physical characters

Plant height: The height of the five randomly selected plants per entries was measured in cm from the ground level to the tip of the stem.

Number of branch per plant: Number of total branches per 5 tagged plants per plot was recorded for each of 10 brinjal varieties at 7 days interval and the average number of total leaves per plant was calculated.

Number of leaves per plant: Number of total leaves per 5 tagged plants per plot was recorded for each of 10 brinjal varieties at 7 days interval and the average number of total leaves per plant was calculated.

Number of fruits per plant: Number of total fruits per 5 tagged plants per plot was recorded for each of 10 brinjal varieties at 7 days interval and the average number of total fruits per plant was calculated.

Single fruit weight per plant: Weight of total fruits per 5 tagged plants per plot was recorded for each of 10 brinjal varieties at 7 days interval and the average weight of total fruits per plant was calculated.

Length of fruit per plant: Length of total fruits per 5 tagged plants per plot was recorded for each of 10 brinjal varieties at 7 days interval and the average length of total fruits per plant was calculated.

Girth of fruit per plant: Girth of total fruits per 5 tagged plants per plot was recorded for each of 10 brinjal varieties at 7 days interval and the average girth of total fruits per plant was calculated.

Weight of fruit per plant: Weight of total fruits per 5 tagged plants per plot was recorded for each of 10 brinjal varieties at 7 days interval and the average weight of total fruits per plant was calculated.

3.10.3 Infestation parameters:

Number of infested shoot per plant: Number of infested shoot per 5 tagged plants per plot was recorded for each of 10 brinjal varieties at 7 days interval and the average number of infested shoot per plant was calculated.

Number of total shoots per plant: The total number of shoots per 5 tagged plants per plot was recorded for each of 10 brinjal varieties at 7 days interval and the average number of shoots per plant was calculated.

Number of infested fruits per plant: Number of infested fruits per 5 tagged plants per plot was recorded for each of 10 brinjal varieties at 7 days interval and the average number of infested fruits per plant was calculated.

Number of total fruits per plant: The total number of fruits per 5 tagged plants per plot was recorded for each of 10 brinjal varieties at 7 days interval and the average number of fruits per plant was calculated.

Weight of infested fruits per plant: Weight of infested fruits per 5 tagged plants per plot was recorded for each of 10 brinjal varieties at 7 days interval and the average weight of infested fruits per plant was calculated.

Weight of total fruits per plant: Weight of total fruits per 5 tagged plants per plot was recorded for each of 10 brinjal varieties at 7 days interval and the average weight of total fruits per plant was calculated.

Infestation intensity: Number of bore per five randomly selected infested fruits per plot for each of 10 varieties was recorded to determine the infestation intensity of fruits.

Plate-6. BSFB on shoot

Plate-7. BSFB on fruit

3.10.4 Relative resistance

Relative resistance of the plants against BSFB was estimated on the basis of shoot and fruit damage severity. Those pest damage grading were done on this basis the grading index followed by Subbratnam and Butani (1981).

Formula for various calculation

Shape Index = Length fruit/fruit diameter,

Volume Index = Length fruit x fruit diameter,

RLPS = Length of peripheral seed ring/Total length of fruit,

RLSA = Length of seed less area/Total length of fruit,

Where, RLPS = Ratio of Length of Peripheral Seed Ring and RLSA = Ratio of Length of Seedless.

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

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

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

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

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

% reduction of fruit length

$$= \frac{(Mean\ length\ of\ healthy\ fruits) - (Mean\ length\ of\ infested\ fruits)}{Mean\ length\ of\ healthy\ fruits} \times 100$$

$$\% \text{ reduction of fruit girth} = \frac{(Mean\ girth\ of\ healthy\ fruits) - (Mean\ girth\ of\ infested\ fruits)}{Mean\ girth\ of\ healthy\ fruits} \times 100$$

3.11 Determination of resistance factor

Length of peripheral seed ring: The length of peripheral seed ring was measured on (cm) scale after dissecting the fruit longitudinally. The ratio of length of peripheral seed ring to total length of fruit (RLPS) was calculated by the length of peripheral seed ring by the total length of fruit.

Length of seedless area: The fruit used for measuring the length of peripheral seed ring were also used to measure the length of seed less area. It was measured both at the lower and upper end from the center and added up. The total was divided by the total length of fruit to work out of ratio of the length of seed less area to total length of fruit (RLPS) on the fruit.

Thickness of pericarp: The breath of area between the peripheral seed ring and the fruit skin measured on mm scale was taken as the thickness of the pericarp.

Thickness of mesocarp: The thickness of mesocarp was calculated by subtracting the thickness of pericarp from the total thickness of fruit.

3.12 Plant biochemical factors for resistance

Many biochemical factors are known to be associated with insect resistance and some biochemical constituents may act as feeding stimuli for insects. Occurrence at lower concentration or total absence of such biochemicals leads to insect resistance (singh et al., 1983). Biochemical factors of the host plant have been reported to play a vital role in resistance to various insect pests and relatively resistant genotypes contained higher amount of phenols inherently (Hanson et al., 2006) as these are often associated with the feeding deterrence, growth inhibition and in higher concentration could ward off insect pests because of the direct toxicity (Shinde et al., 2007). Preneetha et al. (2002) found that while selecting brinjal genotypes for shoot and fruit borer resistance, apart from their performance based on the yield, consideration may also be given on the quantity of biochemical constituents. However, in general various biochemical constituents present in plants showed a considerable level of resistance to insect pests and in brinjal, the low sugar content and higher phenolic compounds offered a significant level of resistance to various biotic stresses (Khorshezzuzaman et al., 2010).

3.12.1 Phenols

Sample of fruit weighing 0.5 g was taken and grinded with the help of mortar and pestle along with 10 ml of 80% ethanol. Later sample were centrifuged at 10, 000 rpm for 20 minutes. Supernatant were saved and residues re-extracted with 5 times volume of 80% ethanol. Samples were centrifuged again at 10, 000 rpm and the supernatants were pooled and later evaporated to dryness then obtained and residue were dissolved in 5ml of distilled water. Aliquots of (0.2 to 2) were pipette out into different test tubes each added by 0.5 ml of Folin-Ciocalteu Reagent (FCR). After 3 minutes, 2 ml of 20% Na_2CO_3 was added and mixed thoroughly. Then tubes were placed in boiling water for exactly 1 minute and pooled. Absorbance was measured in spectrophotometer at 630 nm against reagent blank. Finally standard curve using different concentrations of catechol were prepared. From the standard curve concentration of phenols in the test sample were estimated and expressed as mg of phenols per gram of sample. Standard graph was drown by plotting concentration of standard on the X-axis vs absorbance on Y-axis (Figure-1). From the graph amount of total phenol present in the sample were calculated as.

$$\text{Phenols (mg/g)} = \frac{\text{Micro liters from standard curve x volume x dilution}}{\text{Weight of sample x 1000}}$$

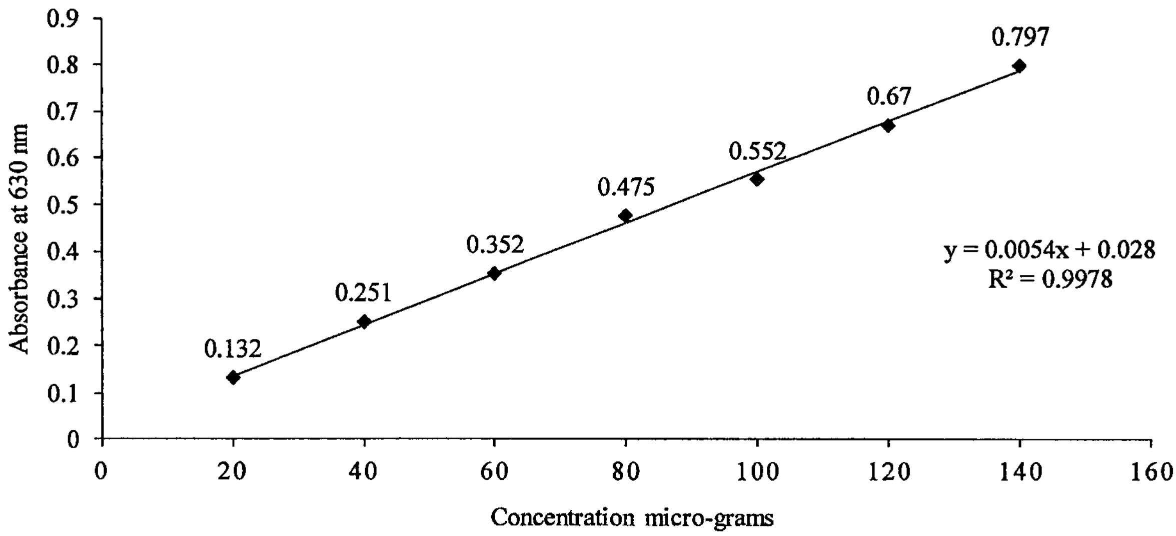


Figure-1: Standard curve for the estimation of phenols in brinjal by Folin-Ciocalteu reagent method as given by Bray and Thrope (1954)

3.12.2 Total sugars

100 mg of the fruit sample were taken and hydrolyzed in a boiling water bath for 3 hours with 5 ml of 2.5 HCl and cooled at room temperature. Then it was neutralized with solid sodium carbonate until the effervescence got ceased and the volume was made to 100 ml and centrifuged at 5000 rpm for 20 minutes. The supernatants were collected and 1 ml aliquots were taken for further analysis. Standards were prepared by taking the 0, 0.2, 0.4, 0.8 and 1ml of working standards while 0 served as blank. Volume was made to 1 ml in all the tubes including sample tube by adding distilled water. 4 ml of anthrone reagent was added to each tube and heated for 8 minutes in a boiling water bath. Then cooled rapidly and green to dark green color were read in spectrophotometer at 630 nm. Standard graph was drown by plotting concentration of standard on the X-axis vs absorbance on Y-axis (Figure-2). From the graph amount of total sugar present in the sample were calculated as.

$$\text{Total sugars (mg/g)} = \frac{\textit{Sugar value from graph } (\mu g)}{\textit{Aliquot sample used } (1\ ml)} \times \frac{\textit{Total volume of extract } (ml)}{\textit{Weight of sample } (mg)}$$

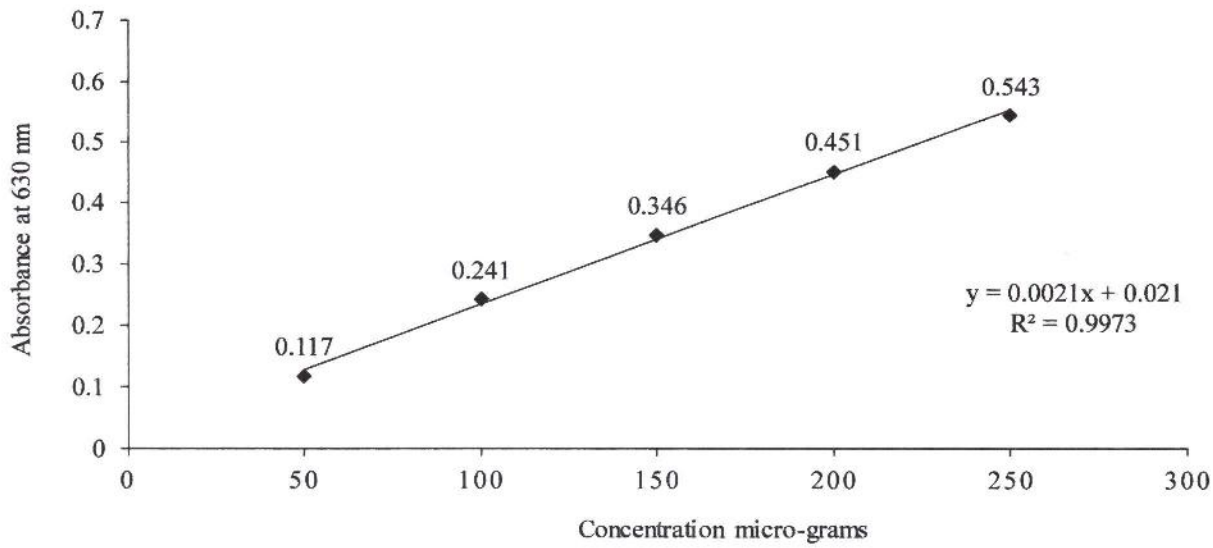


Figure-2: Standard curve for the estimation of sugars in different brinjal genotypes by Anthrone method as given by Sadasivam and Manickam (1992).

3.13 Statistical analyses:

The data was analyzed for the comparison of different germplasm of brinjal. Data were analyzed by using **Statistix 10** software for analysis of variance. ANOVA was made by *f*-variance test and the pair comparisons were performed by HSD Tukey's Test.

CHAPTER 4

RESULTS AND DISCUSSION

The experiment was conducted to evaluate varietal performance of ten brinjal varieties against brinjal shoot and fruit borer (*Leucinodes orbonalis*) in relation to growth characteristics, level of infestation, yield attributes and fruit yield. The results of the study have been presented in this section with discussion under following sub-headings:

4.1 Plant morphological characters

Plant morphological characters like plant height (cm), number of leaves per plant, length of leaf (cm), breath of leaf (cm), number of shoot plant^{-1}, number of infested shoots plant^{-1} were evaluated in different brinjal varieties to correlate the effect of these factors with BSFB infestation. These are described under the following headings:

4.1.1 Plant height

Plant height varied significantly among the varieties where Local Cultivar-4 gave the tallest (85.83 cm) and it was the shortest in BARI begun-4 (45.83 cm) in length among the tested cultivars (Table-1). Plants of other varieties were attended medium height (48 cm-68 cm). BARI Hybrid Begun -4, BARI BT Begun-4, BARI Begun-9 and BARI Begun-10 were statically identical to Local Cultivar-1, Local Cultivar-2 and Local Cultivar-3 but different from other (Table-1). Hossain et al. (2002) found highest plant height in the variety Khotkhotia-1, which was significantly different from that of other varieties. In respect of height, Baromashi was a short variety and the height of this variety significantly identical with that of the varieties Nayankajal, BLO 45, BLO 95 and BLO 101. None of the research found similar with this result of current research due to varietal different as well as different agro-ecological zone.

4.1.2 Number of leaves per plant and leaf size:

In terms of the number of leaf per plant varied significantly among the tested varieties. The highest number of leaves (73.67) were also obtained from Local Cultivar-4 while BARI Begun-10 gave the lowest number (39.89). BARI Hybrid Begun-4, BARI BT-4, Local Cultivar-1, Local Cultivar-2 and BARI Begun-4 were statically similar to each other but different from BARI Hybrid Begun-2, Local Cultivar-3, and Local Cultivar-4. Length and breadth of the leaves of BARI Hybrid

Begun -4 were the highest than the other ones (31 cm, 19.83 cm respectively). The lowest length of leaves found in Local Cultivar-3 (22cm) whereas Local Cultivar-4 showed lowest breadth (11cm). Number of leaf per plant of different brinjal varieties at different plant ages ranged from 5.83 (BLO 45) to 9.7 (Khotkhotia-1) (Hossain et al., 2002).

4.1.3 Number of shoots per plant:

The screened varieties are not significant in terms of number of shoot per plant. The highest number of shoots were found in BARI Begun-10 (39.33) while Local Cultivar-4 gave the lowest number of shoots (26). The highest number of infested shoots were found in BARI Begun-10 (16.67) whereas lowest infested shoots were found in BARI Begun-9 (9). Sharma et al. (2002), Javed et al. (2009), Hossain et al. (2002) evaluated number of shoots as well as number of infested shoots per plant but their results could not be compared with present studies due to difference in genotypes used in their experiments.

Table 1. Growth Parameters of the varieties and shoot infestation

Variety	Plant height (cm)	Average no.of leaves Plant^{-1}	Average length of leaf (cm)	Average breadth of leaf (cm)	No of shoos Plant^{-1}	No. of infested shoots plant^{-1}
BARI Hybrid Begun-2	62.50b	53.33bc	33.00a	18.33ab	30.67	13.67abc
BARI Hybrid Begun-4	55.33bc	50.33b-d	31.00ab	19.83a	28.33	11.00bc
BARI BT Begun-4	57.00bc	45.33b-d	28.67bc	13.00b-d	36.00	14.00abc
BARI Begun-9	53.17bc	44.00cd	26.33cd	14.67a-d	29.00	9.00c
BARI Begun-10	55.23bc	39.89d	30.67ab	19.33a	39.33	16.67a
Local Cultivar-1	51.17bc	57.17b-d	28.50bc	17.00a-c	34.67	12.00ac
Local Cultivar-2	59.17bc	52.67b-d	30.17a-c	13.17b-d	31.67	16.33ab
Local Cultivar-3	49.67bc	58.00b	22.00e	12.00cd	31.67	12.00ac
Local Cultivar-4	85.83a	73.67a	24.33de	11.00d	26.00	11.33ac
BARI Begun-4	45.83c	46.50b-d	27.58b-d	13.17b-d	30.67	16.00ab
Level of Significance	**	**	**	*	NS	*
LSD Value	13.68	13.26	4.10	5.87	-	5.38

Data in a column with same letter do not differ significantly and data with different letter differ significantly. NS= Not significant. **= Significant at 1% level and * = Significant at 5% level.

4.2 Fruit characteristics

The significant variations were observed among different brinjal varieties in terms of fruit characteristics such as fruit length (cm), fruit diameter (cm), shape index, volume index, length of peripheral seed ring, thickness of pericarp (cm), thickness of mesocarp (cm).

4.2.1 Fruit length

The mean length of fruit ranged 6.00 to 26.67 cm (Table-2). Only one genotype viz. Loval cultivar-2 was noticed to bear reduced size fruit (6cm); while 5 genotypes like BARI Begun-4, BARI hybrid Begun-2, BARI Hybrid Begun-4, BARI BT Begun-4 and Local Cultivar-4 had medium length of fruits (7-11 cm). Other four genotype BARI Begun-9, BARI Begun-10, Local Cultivar-1 and Local Cultivar-3 contained extra-long fruits (fruit length 12-22 cm). Local Cultivar-3 reported as the longest fruit (26.67 cm) whereas Local Cultivar-2 (6cm) reported as the shortest one. Sharma et al. (2002) observed highest fruit length in Muktakeshi and Pusa Purple Round (15 cm and 14.9 cm respectedly) and the lowest length reported in Arkakusmakar (4.5cm). Rishi et al. (2018), Yadav et al. (2005) screened fruit length of different genotypes but their results could not be compared with present studies due to difference in genotypes used in their experiments.

4.2.2 Fruit diameter

The screened genotypes were varied significantly in terms of fruit diameter. The fruit diameter were ranged between 2.70 to 9.10 cm (Table-2). Two genotypes were in the range of 0 to 4 cm diameters *viz*, BARI Begun-9 (2.70 cm) and BARI Begun-10 (2.76 cm). Three varieties viz. Local Cultivar-1 (5.66 cm), Local Cultivar-2 (5.90 cm) and Local Cultivar-4 (4.73) was found medium diameter (4 to 6 cm) and the other 5 genotypes viz., BARI Hybrid Begun-2 (6.53 cm), BARI Hybrid Begun-4 (6.07cm), BARI BT Begun-4 (9.10cm) were found as higher diameter. According to Rishi et al. (2018) fruit diameter (FD) was between the ranges of 2.82-7.42 cm. Five genotypes ranges between 0 to 4 cm diameters were thin fruits While 13 genotype had medium diameter (4 to 5 cm) and 22 genotypes had thick fruit.

4.2.3 Shape index

The shape index varied from (1.60 to 2.32) (Table-2). Five genotypes were grouped into round (shape index 1.60-2.86 cm), which were Local Cultivar-3 (1.85), BARI Hybrid Begun-2 (1.81), BARI Hybrid Begun-4 (1.60), BARI Begun-4 (2.21) and BARI Begun-10 (1.60). Four varieties were grouped to oval to longish (shape index 2.10 to 2.32 cm) viz. BARI BT Begun-4 (2.21), Local Cultivar-2 (2.32), Local Cultivar-4 (2.24) and Local Cultivar-1 (2.10). Round genotypes are the infestation percentage range between (53.90 to 80.60) percent, while in oval to longish genotypes the infestation percentage (4.20 to 45.47%). So, this findings revealed that round genotypes are more susceptible against brinjal shoot and fruit borer (Table 2). Sharma et al. (2002) evaluated eight cultivars of brinjal and grouped Muktakeshi and BR-112 as round fruit. On the other hand Arkakumakar, Pusa Purple Cluster and Pusa Purple Round as oval shaped fruit.

4.2.4 Volume index

Volume index varied from 250-630. Lowest volume index (264) was found in Local cultivar-3 which was statistically similar with Local cultivar-4. BARI Hybrid Begun-4 showed highest volume index (614) which was statistically similar with BARI Hybrid Begun-2 but different from others (Table-2).

4.2.5 Length of peripheral seed ring and seedless area

The ratio of the length of peripheral seed ring to total length of the fruit (RLPS) indicating the degree of mechanical seed barrier to the entry of borer varied from (0.132 to 0.641) as given in (Table-2). The less RLPS (0.132 to 0.189) was observed in five genotypes, which were BARI Hybrid Begun-4 (0.132), BARI Begun-4 (0.137), BARI hybrid Begun-2 (0.140), BARI BT Begun-4 (0.163) and Local Cultiva-2 (0.189). The medium RLPS (0.203 to 0.348) was found in four varieties, which were Local Cultivar-1 (0.203), Local Cultivar-3 (0.249), Local Cultivar-4 (0.300) and Bari Begun-10 (0.348). The highest RLPS (above 0.500) was recorded from only one variety named BARI Begun-9 (0.641). The ratio of length of seedless area to the total length of fruit indicating the pulpiness of fruit ranged between 0.060 to 0.198. The ratio of seedless area are less (0.100 to 0.200) ranged in all the genotypes under study are BARI Hybrid Begun-2, 2. BARI Hybrid Begun-4, 3. BARI BT Begun-4, 4. BARI Begun-9, 5. BARI Begun-10, 6. Local Cultivar-

1, 7. Local Cultivar-2, 8. Local Cultivar-3, 9.Local Cultivar-4, 10. BARI Begun-4. The higher RLSA (above 0.301) was not found in any of the varieties one genotypes (Table 2).

4.2.6 Thickness of pericarp

The pericarp thickness of fruit varied from (0.23 to 0.61 cm) (Table 2). Only one genotype was found with medium pericarp (0.15 to 0.35 cm), which was BARI Begun-9 (0.23 cm). The other 9 varieties had broader pericarp (0.36 to 0.61 cm). Rishi (2018) evaluated that the pericarp thickness of fruit varied from (0.28 to 1.11 cm).The four genotype with medium pericarp (0.15 to 0.35cm) are SM-10, Long Green Mysore, AC-3698, and S-10-1.They found thirty genotype with broader pericarp (0.36 to 0.70 cm) and the six genotypes with higher pericarp (above 0.76 cm)

4.2.7 Thickness of mesocarp

The thickness of mesocarp varied between 1.83 to 10.82 cm (Table-2). The narrow mesocarp (1 to 2.78 cm) was found in four genotypes i.e. Local Cultivar-2 (2.78 cm), Local Cultivar-3 (1.87 cm), Local Cultivar-4 (2.43 cm), BARI Begun-4 (1.83 cm). The medium mesocarp was measured from three varieties ranged (7.0 to 8.98 cm) viz. BARI Hybrid Begun-2 (8.98 cm), BARI Hybrid Begun-4 (8.86 cm) and Local Cultivar-1(7.39 cm). The broader mesocarp was calculated from three varieties ranged above 10.0 cm, which were BARI BT Begun-4 (10.78 cm), BARI Begun-9 (10.01 cm) and BARI Begun-10 (10.82 cm). Forty germplasms were screened by Rishi et al. (2018) who observed that thickness of mesocarp varied between 1.96 to 5.86 cm. The narrow mesocarp (1 to 2.5 cm) was in four genotypes. The broader mesocarp of four genotypes ranged (above 5.0 cm) is BR-112, Pant Samrat, BR-8654, and BR-42. Kumar and Shukla. (2002) screened different brinjal varieties but their results are not parallel with present study due to variations in antixenotic and antibiotic behavior of host plamt genotypes.

Table 2. Characteristics of brinjal fruit in relation to shoot and fruit borer incidence

Germplasm	Fruit length (cm)	Fruit diameter (cm)	Shape index (l/d)	Volume index (lxd)	RLPS	RLSA	Thickness of Pericarp (cm)	Thickness of Mesocarp (cm)	Fruit infestation (%)
BARI Hybrid Begun-2	9.54b	6.53cd	1.81bc	605.00a	0.140d	0.117bc	0.47ab	8.98a-c	80.6a
BARI Hybrid Begun-4	7.78b	6.07de	1.60c	614.83a	0.132d	0.156ab	0.55ab	8.86a-c	75.6a
BARI BTBegun-4	10.61b	9.10a	2.21ab	373.00bc	0.163cd	0.195a	0.61a	10.78a	4.20c
BARI Begun-9	19.78ab	2.70g	1.86a-c	392.67a-c	0.641a	0.061c	0.23c	10.01ab	34.2bc
BARI Begun-10	21.39ab	2.76g	1.60c	592.00ab	0.347b	0.116bc	0.43b	10.82a	53.9ac
Local Cultivar-1	13.44ab	5.66e	1.78bc	507.25ab	0.20b-d	0.154ab	0.48ab	7.39ab-d	71.9ab
Local Cultivar-2	6.00b	5.90de	2.32a	400.83a-c	0.189cd	0.156ab	0.52ab	2.78b-d	55.2ac
Local Cultivar-3	26.67a	7.29bc	1.85a-c	264.00c	0.249b-d	0.198a	0.51ab	1.87cd	72.8ab
Local Cultivar-4	9.70b	4.73f	2.24ab	268.33c	0.300bc	0.146ab	0.43b	2.43cd	57.5ac
BARI Begun-4	8.06b	7.81b	2.10ab	367.58bc	0.137d	0.188a	0.56ab	1.83cd	45.5ac
Level of Significance	*	**	*	*	*	*	*	*	*
LSD Value	13.98	0.87	0.46	224.56	0.155	0.066	0.17	7.37	35.98

Data in a column with same letter do not differ significantly and data with different letter differ significantly. **= Significant at 1% level, *= Significant at 5% level.

4.3 Yield contributing characters and yield of fruit

4.3.1 Number of flowers per plant

Fruit characteristics are considered as the important ones for resistant breeding and fruit yield. There were significant differences among the brinjal varieties in respect of yield contributing character and yield (Table-3). The highest number of flowers and fruits were found in Local Cultivar-4 (106 and 32, respectively) and those were the lowest in BARI Begun-4 (44.33 and 9.00, respectively). Flower number of rest of the varieties ranges from 56-86. BARI Hybrid Begun-4, BARI BT-4, BARI Begun-9 and BARI Begun-10 were statistically similar with Local Cultivar-1, Local Cultivar-2, and Local Cultivar-3 but did not differ significantly with others. Rishi et al. (2018) and Yadav et al. (2005) screened number of flowers per plant in different genotypes but their results could not be compared with our present studies due to difference in genotypes used in their experiments.

4.3.2 Number of larvae per fruit

The highest infested fruits and larvae were obtained from BARI Hybrid Begun-2 and BARI Hybrid Begun-4 (21.67 and 13.33, respectively). Average fruit weight per plant was the highest (9.53 kg) and weight of individual fruit in BARI BT Begun-4 (273.63 g). Average yield was recorded from Local Cultivar-3 (165.00 t/ha) followed by BARI BT Begun-4 (99.23 t/ha). According to Javed et al. (2009) means comparison of the data pertaining to number of larval population per leaf showed significantly different response of cultivars during 2007. The cultivar Naeelam showed maximum larval population per leaf (1.14), while Nirala was proved comparatively less preferred by larvae of the brinjal shoot and fruit borer. This result varied from present study due to difference in antibiotic and antixenotic behavior of host plant genotypes.

Table 3. Yield contributing parameters and yield of the varieties and number of larvae

Variety	No. of flowers plant^{-1}	Total no. of fruits plant^{-1}	No. of infested fruit plant^{-1}	No. of larvae plant^{-1}	Average fruit weight plant^{-1} (Kg)	Weight of individual fruit (g)	Yield (t ha^{-1})
BARI Hybrid Begun-2	56.67b	27.0ab	21.67a	9.67ab	7.23b d	133.67d	115.42b
BARI Hybrid Begun-4	73.67ab	23.7ac	17.67ab	13.33a	7.97ab	94.47e	71.45cd
BARI BT Begun-4	63.0ab	21.3b-d	1.00e	2.00e	6.27bd	273.63a	99.23bc
BARI Begun-9	67.0ab	14.33de	5.33de	3.67de	5.23d	74.50f	33.84d
BARI Begun-10	71.67ab	15.33c-e	8.00ce	5.00ce	5.53d	79.23f	38.69d
Local Cultivar-1	75.33ab	20.67b-d	14.6ac	4.00de	7.56ac	136.40d	90.23bc
Local Cultivar-2	80.67ab	17.0ce	13.0bd	6.00be	6.93bd	131.47d	71.55cd
Local Cultivar-3	86.00ab	27.33ab	20.6ab	7.67bd	9.53a	188.27c	165.0a
Local Cultivar-4	106.0a	32.00a	18.3ab	9.00bc	7.73ab	64.50g	66.24cd
BARI Begun-4	44.33b	9.0e	4.0e	2.33e	5.60cd	206.34b	59.68cd
Level of Significance	**	**	**	**	**	**	**
LSD Value	44.37	9.16	7.99	4.28	2.03	6.23	41.22

Data in a column with same letter do not differ significantly and data with different letter differ significantly. **= Significant at 1% level.

4.4 BSFB infestation level in brinjal

4.4.1 Shoot infestation

There were significant variations among the varieties in respect of shoot infestation (Table 4). Infestation percent of shoot by BSFB was recorded in brinjal germplasm, ranged from 9 to 52.33%. The highest shoot infestation (52.33%) was recored in BARI Begun-4, which was statistically similar to Local Cultivar-2 (51.40%) followed by Local Cultivar-4 (43.67%). The lowest shoot infestation was recorded from BARI BT Begun-4 (9%). Percentage of shoot infestation in BARI Hybrid Begun-4 (39.13%) statistically similar with Local Cultivar-1 (32.33%) and Local Cultivar-3 (36.67%). Rahman et al (2008) screened 20 brinjal genotypes of India and found highest shoot infestation in the varieties Bijoy (4.54), Kaikka N (6.05), Kaikka N (5.81) and Bijoy (4.65) at 60, 80, 100 and 120 DAT respectively while Borka (1.65), Katabegun WS (1.60), Katabegun WS (1.99) and Marich begun S (1.41) at 60, 80, 100 and 120 DAT respectively showed the lowest infestation. Javed et al. (2009) observed maximum shoot infestation was on the cultivar Naeelam (43.15%) followed by Kanha-091 with 37.72% shoot infestation. Cultivar Nirala had minimum (19.27%) shoot infestation. During second year of the study (2008), minimum shoot infestation was observed in Nirala (15.81%) which was statistically similar with EP273 having 16.55 % shoot infestation. Shoot infestation level of our studied varieties was found distinct from findings of cited references, which is due to variation of genotypes selection.

4.4.2 Fruit infestation

In terms of fruit infestation ten brinjal genotypes screened in current research varied significantly. The highest fruit infestation reported in BARI Hybrid Begun-2 (80.6%) which was statistically similar with BARI Hybrid Begun-4 (75.60%) and Local Cultivar-3 (72.77%) while the lowest fruit infestation found in BARI BT Begun-4 (4.2%). Javed et al. (2009) observed maximum fruit infestation on Naeelam (58.60%) followed by Black long (47.93%) during first year of studies. Nirala showed minimum infestation (24.75%) which differed significantly from all other cultivars. Shigaonkar et al. (2021) observed the report based on mean per cent fruit infestation recorded 85 days after transplanting indicated that the cultivar Singnath (6.18) showed the lowest mean per cent fruit infestation which was significantly less than rest of the cultivars, except the cultivars viz., CHES-249, Bholanath, Kali rawai, BB54, (7.14, 8.33, 8.33, 9.09 mean per cent fruit infestation respectively). The mean per cent fruit infestation ranged from 6.18 to 27.27 per cent.

Comparable range of fruit infestation was 20.23 to 45.61% reported by Jat. (2003), though they used different set of varieties/cultivars in their experiment. Similarly, Krishna et al. (2001) found 43% fruit infestation in Ramy round purple of India which was comparatively the most susceptible while minimum shoot infestation was reported in SM-02. Kumar and Shukla (2002) recorded that 33 to 53% damage of fruits in 12 different cultivars of brinjal. Similarly, Ashoke and Abhishek (2002) estimated that 33.65- 53.02% fruit infestation of *L. orbonalis* larvae while evaluating 12 brinjal cultivars in field conditions. In 2000, Chaudhary and Sharma noticed very low attack of brinjal shoot and fruit borer (2.88-5.64%) during screening of nine genotypes of brinjal. Gangopadhyay et al. (1996) found infestation of *L. orbonalis* in every variety under investigation. They also suggested exotic varieties were more susceptible than local ones. Sharma et al. (1998) evaluated the response of 8 cultivars of brinjal for tolerance against *L. orbonalis.* In our screening trail, the ten brinjal varieties we have tested differed from the results of above citations in terms of shoot and fruit infestation due to the variability in their genetic makeup as well as difference in soil nutritional status and microclimatic variation.

4.5 Categorization of genotype

All the 10 genotypes of brinjal were categorized as per Subbratnam and Butani (1981) for their reaction to shoot and fruit borer *Leucinodes orbonalis* Guene. General equilibrium position of shoot infestation of different entries of brinjal was calculated on the basis of their infestation, which is varied between 9.0 to 52.33% shoot infestations (Table 4 and 5). Only one genotype of brinjal viz, BARI BT Begun-4 had 9.00% shoot infestation showing tolerance against this pest. Four entries like, BARI Hybrid Begun-4, BARI Begun-9, Local Cultivar-1 and Local Cultivar-3 were susceptible against this pest and other 5 varieties namely BARI Hybrid Begun-2, BARI Begun-4 BARI Begun-10, Local Cultivar-2 and Local Cultivar-4 were categorized as highly susceptible genotype, respectively (Table 5). None of the varieties were found moderately tolerant and resistance against fruit borer. Another categorization of tested entries against shoot and fruit borer done on the basis of rank allotted to the shoot as well as fruit infestation.

Table 4. Categorization of different germplasm of brinjal by ranking method based on shoot & fruit infestation as per Subbratnam and Butani (1981)

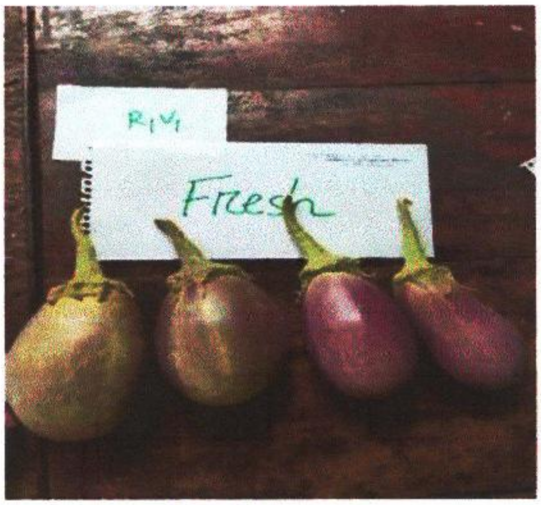
Germplasm	Shoot Infestation (%)	Rank	Fruit Infestation (%)	Rank
BARI Hybrid Begun-2	43.27bc	HS	80.60a	HS
BARI Hybrid Begun-4	39.13cd	S	75.60a	HS
BARI BT Begun-4	9.00cde	T	4.2c	T
BARI Begun-9	34.50ef	S	34.20bc	S
BARI Begun-10	42.50bc	HS	53.90a-c	HS
Local Cultivar-1	32.33f	S	71.93ab	HS
Local Cultivar-2	51.40a	HS	55.23a-c	HS
Local Cultivar-3	36.67d-f	S	72.77ab	HS
Local Cultivar-4	43.67b	HS	57.50a-c	HS
BARI Begun-4	52.33a	HS	45.47a-c	HS

Tolerance (T), Susceptible (S) and Highly Susceptible (HS). Data in a column with same letter do not differ significantly and data with different letter differ significantly.

Table 5. Categories of the brinjal varieties of the present study based on average rank of shoot and fruit infestation as per Subbratnam and Butani (1981)

Category	Range of infestation	Name of germplasm based on	
		Shoot infestation	Fruit infestation
Highly Resistance (HR)	‹ 5%	0	0
Resistance	5.1-15	BARI BT Begun -4	BARI BT Begun -4
Moderately Resistance (MR)	15.1-25%	0	0
Susceptible(S)	25.1-40.0%	BARI Hybrid Begun-4, BARI Begun-9, Local Cultivar-1 and Local Cultivar-3	BARI Begun-9
Highly Susceptible (HS)	Above 40%	BARI Hybrid Begun-2, BARI Begun-10, Local Cultivar-2, Local Cultivar-4 and BARI Begun-4	BARI Hybrid Begun-2, BARI Hybrid Begun-4, BARI Begun-10, Local Cultivar-1, Local Cultivar-2, Local Cultivar-3, Local Cultivar-4 and BARI Begun-4

Level of resistance in any genotype is governed by genetic character and ecological interaction. However, variation in degree of infestation of any pest is the combined effect of genetic architecture of crop variety and abiotic factor. Workers of screening of germplasm/ variety of brinjal have been carried out in different part of the word by various scientists. Kumar et al. (2002) found none of the cultivar free from fruit borer infestation. The Kali rawai and the cultivars viz., Singnath, CHES-249 and Arka Nilkanth were categorized as highly resistant whereas the cultivar Swarn Pratibha, PPC, Bholanath, BB 60 C, BB 54, BGTP-2, RCMB-3 and Arka Nidhi were categorized as fairly resistant. The cultivars Lanja Local, Asond Local and Sushivare Local were categorized as less susceptible or tolerant. The work of Jat (2003), showing SM-10 as resistant against fruit borer and Pusa Purple Long against shoot borer. Yadav et al. (2003), also reported that brinjal variety Puas Purple Long was least susceptible against shoot and fruit borer under field condition in Rajasthan. Yadav and Sharma (2005) also reported Pusa Purple Long as relatively less susceptible variety of brinjal shoot and fruit borer. The germplasm cited above are varied significantly with current research due to the variability in their genetic makeup as well as difference in soil nutritional status and microclimatic variation. So, it can be mentioned that breeding program of this crop is necessary for development of resistant variety of pure line.

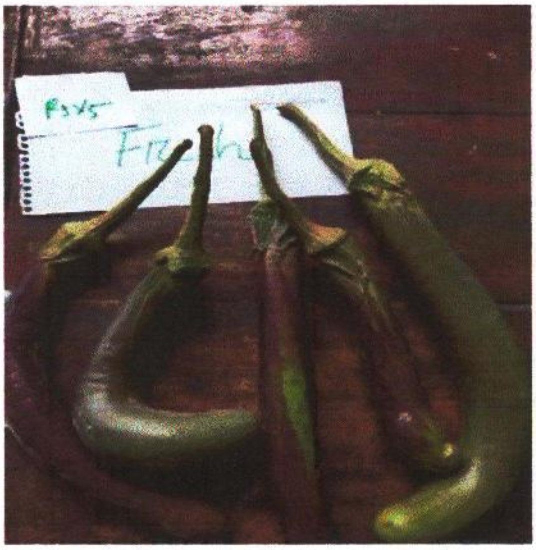


V_1: BARI Hybrid Begun-2

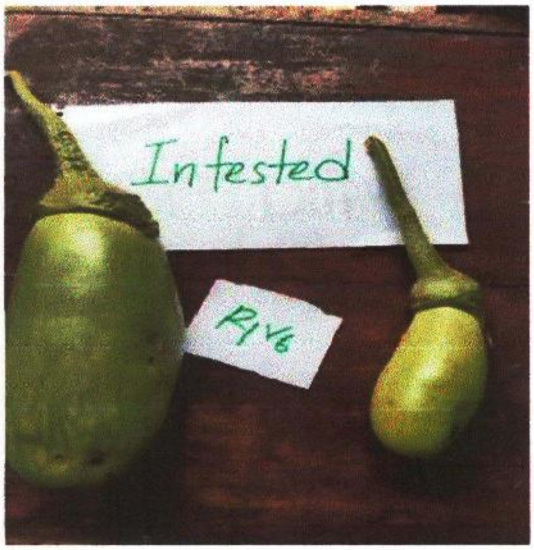
V_2: BARI Hybrid Begun-4

V_3: BARI BTBegun-4

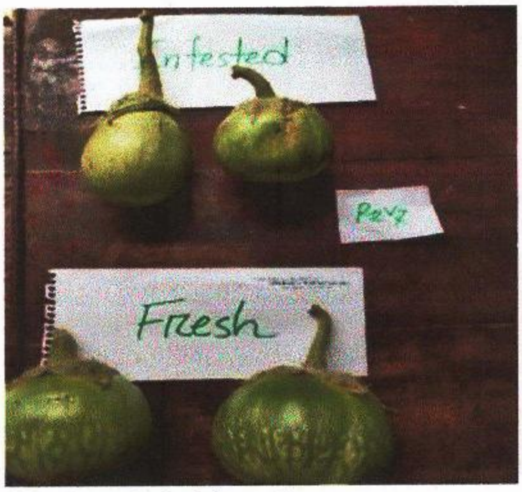
V_4: BARI Begun-9



V_5: BARI begun-10



V_6: Local Caltivar-1



V_7: Local Caltivar-2

V_8: Local Caltivar-3

V_9: Local Caltivar-4

V_{10}: BARI Begun-4

Plate-8. Comparative appearance of fresh and BSFB infested brinjal fruits

4.6 Impact of biochemical factors on BSFB shoot and fruit infestation

4.6.1 Total phenolic content and BSFB infestation

In case of total phenolic compound, brinjal varieties differed significantly. Among ten varieties highest phenolic content was found in BARI-BT Begun 4 (1.3 mg/g) with lowest shoot infestation (9%) and fruit infestation (4.2%) while lowest amount was found in BARI-Begun 4 (0.41mg/g) with highest shoot infestation (52.33%). BARI Hybrid Begun-2 shows highest fruit infestation (80.60%) with very low amount of phenolic compound (0.51 mg/g). The 2nd lowest fruit infestation observed in BARI Begun-9 with very higher amount of phenolic compound (0.78 mg/g). This finding is analogous to the observations made by Prasad et al. (2014), Docimo et al. (2016) and Khorsheduzzaman et al. (2010) who found that selection of genotypes with higher glycoalkaloid (solasodine), total phenols and polypheol oxidase activity improve resistance to shoot and fruit borer infestation. Dar et al. (2017) observed higher level of total phenol activity in resistant Brinjal-85 and Local long. Shalimar Brinjal Hybrid-1 and 2, showed maximum shoot infestation of 9.10, 8.69 and fruit infestation of 23.07 and 22.0 percent, respectively, recorded higher content of total sugars and lower content of total phenols, respectively which is very parallel to current findings. Prabhu et al. (2014) observed that total phenol content and its activity is higher in shoots as compared to fruits at all stages of growth. Also, the Phenol content is the one of the most important character to reduce the shoot and fruit borer incidence. If the phenol content is high borer infestation will be less which is very parallel to present investigation.

4.6.2 Total sugar content and BSFB infestation

In case of total sugar content, brinjal varieties differed significantly. Among ten varieties highest sugar content was found in Local cultivar-1 (12.4 mg/g) with very high shoot infestation (32.33%) and fruit infestation (71.93%) while lowest amount was found in BARI BT-Begun 4 (4.56mg/g) with lowest shoot infestation (9%) and fruit infestation (4.2%). BARI Hybrid Begun-2 shows highest fruit infestation (80.60%) with very high amount of sugar content (10.2 mg/g). Table-6 reported that highest sugars content recorded in highly susceptible accession viz BARI Hybrid Begun-2, BARI Hybrid Begun-4, Local Cultivar-1, Local Cultivar-4 and BARI Begun-4. The results are in agreement with Shine et al. (2007), Prasad et al. (2014) and Docimo et al. (2016) who found that susceptible genotypes contain higher content of total sugars as compared to resistant ones. Genotypes *viz*., Brinjal-85 and Local Long provided less feeding stimulus to borers due to high phenols and low total soluble sugars, thus could be utilized in the breeding program for the development of shoot and fruit borer resistant varieties in brinjal.

Khorsheduzzaman et al. (2010) found that in brinjal, sugar content acted as a feeding stimulant to the borers. For this reason susceptible genotypes contain higher content of sugars as compared as resistant ones which is in agreement with present investigation.

Table-6: Phenols and total sugar content of brinjal varieties against shoot and fruit infestation

Variety	Shoot infestation (%)	Fruit infestation (%)	Total phenol content (mg/g)	Total sugar content (mg/g)
BARI Hybrid Begun-2	43.27bc	80.60a	0.47de	10.2c
BARI Hybrid Begun-4	39.13cd	75.6a	0.53de	10.1c
BARI BT Begun-4	9cde	4.2c	1.3a	4.56g
BARI Begun-9	34.5ef	34.20bc	0.78b	6.01f
BARI Begun-10	42.5bc	53.9a-c	0.65cd	8.18e
Local Cultivar-1	32.33f	71.93ab	0.72bc	12.4a
Local Cultivar-2	51.40a	55.23a-c	0.46e	9.03d
Local Cultivar-3	36.67d-f	72.77ab	0.67cd	9.12c
Local Cultivar-4	43.67b	57.50a-c	0.55de	10.1c
BARI Begun-4	52.33a	45.47a-c	0.41e	12.3b
Level of Significance	**	*	***	***
LSD Value	15.23	35.95	0.20	0.84

Data in a column with same letter do not differ significantly and data with different letter differ significantly. ***= Significant at 0.1% level, **= Significant at 1% level and * = Significant at 5% level.

4.6.3 Association between biochemical factors and BSFB infestation

Plant biochemical factors like phenols and total sugars had significant co-relations with shoot and fruit infestation. There was negative significant relation among phenols, total sugars (r= -0.478*, r=0.392* respectedly) with shoot and fruit infestation. This result is similar with Shinde et al. (2007) who found that phenols are negatively correlated with the borer damage and are responsible to impart resistance. Phenolic compounds are an important component of the oxidative defenses of plants against pests, when compounds become oxidized in midgut of insects and their reaction products are responsible for causing oxidative stress in the digestive tract producing reactive oxygen species (ROS). Tripati et al. (2014) who found positive significant co-relation between total sugars with shoot and fruit borer which is analogous to present study. They stated that the higher the amount of total sugars the higher the shoot and fruit borer infestation.

Table -7: Relationship of biochemical factors with shoot and fruit infestation

Character	Phenols	Total sugars	Shoot infestation (%)	Fruit infestation (%)
Phenols	-	-	-	-
Total sugars	-0.874**	-	-	-
Shoot infestation (%)	-0.478*	0.589**	-	-
Fruit infestation (%)	-0.392*	0.425**	0.365	-

**= Significant at 1% level and *= Significant at 5% level.

4.7 Relationship of Fruit infestation with their Character

Correlation matrix between fruit infestation and fruit length, fruit diameter, shape index, volume index, RLPS (Ratio of Length of Peripheral Seed ring), RLSA (Ratio of Length of Seedless Area) and thickness of pericarp and mesocarp was develop to asses of effect of fruit character on the infestation of fruit borer (Table-8). It was observed that shape index, RLSA and pericarp has significant negative association with fruity infestation (r = -0.334, -0.365 and -0.384, respectively), whereas thickness of mesocarp was positively significantly correlated (r = 0.445) that means if thickness of mesocarp is more infestation will be more. Other factors like fruit length, fruit diameter, volume index and RLPS had non-significant impact in fruit infestation. However, the shape index is the ratio of fruit length and fruit diameter; fruit length had negative association with fruit infestation, while fruit diameter was associated positively. This indicated that enhancement in fruit length reduces the fruit infestation. Whereas the fruit diameter increases the infestation (Table-8).). This result were in agreement with Rishi et al. (2018) who observed negative non-significant relation between Fruit length and fruit infestation (r= -0.649) whereas fruit diameter positively co-related with fruit infeatation (r= 0.235). They also found positive significant relationship between thickness of mesocarp and fruit infestation (r= 0.511) whereas other factors like volume index, RLSA, RLPS and thickness of pericarp were non-significant with fruit infestation.

Table-8. Relationship of fruit infestation with fruit characters in brinjal.

Character	Fruit Diameter	Shape index	Volume index	RLPS	RLSA	Pericarp thickness	Mesocarp thickness	Fruit infestation
Fruit length	0.731**	-0.334	0.850**	-0.347	-0.281	0.128	0.518**	-0.091
Fruit diameter		-0.861**	0.978**	-0.124	-0.400*	-0.114	0.858**	0.322
Shape index			-0.747**	-0.041	0.356*	0.237	-0.810**	-0.334
Volume index				-0.207	-0.383*	-0.045	0.804**	0.260
RLPS					0.667**	-0.807**	0.318	0.350
RLSA						0.899**	-0.785**	-0.365*
Pericarp thickness							-0.609**	-0.384*
Mesocarp thickness								0.455*

**= Significant at 1% level and *= Significant at 5% level.

RLPS= Length of peripheral seed ring/Total length of fruit,

RLSA = Length of seed less area/Total length of fruit,

CHAPTER 5

SUMMARY, CONCLUSION AND RECOMMENDATION

A series of studies were conducted to determine the resistant screening of different brinjal varieties against shoot and fruit borer, *Leucinodes orbonalis* at the germplasm center, Khulna University, Khulna, Bangladesh during September 2020 to May 2021.

Considering the efficiency of different brinjal varieties against brinjal shoot and fruit borer on different parameters, the findings and results have been summarized below:

In terms of percent shoot infestation throughout the growing period of brinjal, Local cultivar-1 showed the best performance against brinjal shoot and fruit borer as 32.33% shoot infestation recorded and the highest percentage of shoot infestation was observed (252.33%) in case of BARI Begun-4. That means, BARI Begun-4 is the most suitable variety for shoot infestation by brinjal shoot and fruit borer and Local cultivar-1 is the least suitable variety for shoot infestation.

In terms of percent fruit infestation by number throughout the growing period brinjal, , BARI Hybrid Begun-4 showed highest infestation percentage (75.6%) by brinjal shoot and fruit borer and the lowest fruit infestation by number was observed in terms of BARI BT Begun-4 (4.2%) throughout the growing period of brinjal.

In terms of leaf number per plant, the highest number of leaves per plant was observed (73) in case of Local Cultivar-4 On the other hand, lowest number of leaves per plant (39) was observed in case of BARI Begun-10.

In terms of number of fruits per plant, results revealed that highest number of fruits per plant was observed (32) in terms of Local Cultivar-4. Similarly the lowest number of fruits per plant has been observed (9) in BARI Begun-4.

In terms of single fruit length (cm) the highest single fruit length has been reported (21.39cm) in case of BARI Begun-10.The lowest single fruit length was reported (9.7)cm by Local Cultivar-4.

In terms of single fruit diameter, the highest data has been reported (2.70 cm) in case of BARI Begun-9 and the lowest single fruit girth was reported (9.10)cm by BARI BT Begun-4.

In terms of single fruit weight the highest result observed (273.6g) by BARI BT Begun-4. On the other hand lowest single fruit weight observed (64.50g) in Local Cultivar-4 throughout the growing period of brinjal.

Highest phenolic content was found in BARI-BT Begun 4 (1.3 mg/g) with lowest shoot infestation (9%) and fruit infestation (4.2%) while lowest amount was found in BARI-Begun 4 (0.41mg/g) with highest shoot infestation (52.33%).

Highest sugar content was found in Local cultivar-1 (12.49 mg/g) with very high shoot infestation (32.33%) and fruit infestation (71.93%) while lowest amount was found in BARI BT-Begun 4 (4.56mg/g) with lowest shoot infestation (9%) and fruit infestation (4.2%). BARI Hybrid Begun-2 shows highest fruit infestation (80.60%) with very high amount of sugar content (10.2 mg/g).

CONCLUSION

It can be concluded from the present experiment that out of the 10 Local and improved genotypes of brinjal screened against shoot and fruit borer, none was found completely free from infestation of the devastating shoot and fruit borer. However, the genetically modified brinjal variety BARI BT Bgun-4 was recorded resistant or tolerant with lowest percent of shoot and fruit infestation (rating scale 1), ascertaining moderate yield (99.23 t/ha). According to biochemical assays, brinjal genotypes with relatively high phenolic concentration and low sugar content were found more preventive to BSFB infestation. Despite BARI BT Bgun-4 is resistant or tolerant to BSFB with low in yield and less preferred by consumer, it is suggested to develop an elite variety of brinjal by incorporating resistant and high yielding brinjal genotypes.

RECOMMENDATION

Considering the findings of the study the following recommendations can be drawn:

- In the context of total yield production, Local Cultivar-3 can be recommended as a suitable variety to cultivate. But resistant mechanisms in the tested genotypes are not up to the expectations. So, further study should carried out to improve this genotype via conventional or advanced breeding technique.
- In the context of resistant mechanisms and morphological characters, BARI BT Begun-4 is the most appropriate variety but yield is comparatively poor than other varieties. So, further study should be focused on enhancing agronomic attributes in BARI BT Begun-4
- More brinjal varieties should be included in further field trails for finding out the promising resistant genotypes for eco-efficient control of brinjal shoot and fruit borer (BSFB).

CHAPTER 6

REFERENCES

Abhishek, T. S., & Dwivedi, S. A. (2021). Review on integrated management of brinjal shoots and fruit borer, Leucinodes orbonalis (Guenee). *Journal of Entomology and Zoology Studies*, 9(1). 181-189

Ahmed, M. S., Rashid, M. A., Hossain, A. K. M. A., & Abdullah, A. (1985). Comparative susceptibility of different cultivars against *Leucinodes orbonalis* Guen. *Bangladesh Hort*, 9, 19-25.

Akter, A., Rahman, M. M., and Tareque, M. H. (2018). Development of an Integrated Pest Management Packages Based on Effective Insecticides and Bio-pesticides for Controlling Tomato Fruit Borer. *Advances in Research*, 1-15.

Alam, S. N., Hossain, M. I., Rouf, F. M. A., Jhala, R. C., Patel, M. G., Rath, L. K., & Talekar, N. S. (2006). Implementation and promotion of an IPM strategy for control of eggplant fruit and shoot borer in South Asia (Vol. 36). AVRDC.

Amin, M. R., Miah, M. S., Rahman, H., Nancy, N. P., & Bhuiyan, M. K. A. (2018). Functional and group abundance of insects on eggplant. *Bangladesh Journal of Agricultural Research*, 43(4), 647-653.

Amin, R., Ali, A. R., Akter, T., & Yesmin, M. (2014). Evaluation of some botanical and chemical insecticides for eco-friendly management of brinjal shoot and fruit borer (*Leucinodes orbonalis*, guenee). *Int. J. Sustain. Agril. Tech*, *10*(11), 15-21.

Azad, A. K., Goshami, B. K., Rahman, M. L., Malakar, P. K., Hasan, S., & Rahman, H. H. (2017). Edited Krishi Projukti Hatboi (Handbook on Agro-technology). Bangladesh Agriculture Research Institute (BARI), Gazipur-1701, Bangladesh.

BBS, (2020). Yearbook of Agricultural Statistics-2019 (Vol. 31st series). Bangladesh Bureau of Statistics (BBS). The Ministry of Planning, People's Republic of Bangladesh. https://bbs.portal.gov.bd/sites/default/files/files/bbs.portal.gov.bd/page/.

Bhushan, S., Chaurasia, H. K., & Shanker, R. A. V. I. (2011). Efficacy and economics of pest management modules against brinjal shoot and fruit borer (*Leucinodes orbonalis*). *Bioscan*, 6(4), 639-642.

Braga, P. C., Scalzo, R. L., Dal Sasso, M., Lattuada, N., Greco, V., & Fibiani, M. (2016). Characterization and antioxidant activity of semi-purified extracts and pure delphinidin-glycosides from eggplant peel (*Solanum melongena* L.). *Journal of functional foods*, 20, 411-421.

Butani, D. K., & Jotwani, M. G. (1984). Insects in vegetables. Periodical Expert Book Agency. D-42, Vivek Vihar, Delhi-110032, India, 356.

Chakraborti, S., & Sarkar, P. (2011). Management of *Leucinodes orbonalis* Guenee on eggplants during the rainy season in India. Journal of Plant Protection Research.

Chatterjee, M. L., & Mondal, S. (2011, March). Sustainable management of key lepidopteran insect pests of vegetables. In *I International Symposium on Sustainable Vegetable Production in Southeast Asia 958* (pp. 147-153).

Chaudhary, D. R., & Sharma, S. D. (2000). Screening of some brinjal cultivars against bacterial wilt and fruit borer. *Agric. Sci. Digest*, 20(2), 129-130.

Dar, S. A., Wani, A. R., Rather, B. A., Parey, S. H., & Kandoo, A. (2017). Biochemical basis of resistance in brinjal genotypes against shoot and fruit borer (*Leucinodes Orbonalis,* Guenee). *Chem Sci Rev Lett*, *6*(22), 1062-1073.

Dash, L., Lakshmi, V. R., & Padhy, D. (2020). Host Range, Life Aspects and Mode of Damage of Brinjal Shoot and Fruit Borer (*Leucinodes orbonalis* Guenee) on Brinjal: A Review. *International Journal of Agriculture, Environment and Biotechnology*, *13*(1), 81-85.

Daunay, M. C. (2008). Eggplant. In *Vegetables II* (pp. 163-220). Springer, New York, NY.

Daunay, M. C. and Hazra, P. 2012. "Eggplant," in Handbook of Vegetables, eds K. V. Peter and P. Hazra (Houston, TX: Studium Press), 257–322.

Dey, S. (2019). Evaluation of some novel insecticides on brinjal shoot and fruit borer (BFSB) in West Bengal, India. *The Pharma Innovation Journal*, 8(12): 337-341.

Docimo, T., Francese, G., Ruggiero, A., Batelli, G., De Palma, M., Bassolino, L., & Tucci, M. (2016). Phenylpropanoids accumulation in eggplant fruit: characterization of biosynthetic genes and regulation by a MYB transcription factor. *Frontiers in Plant Science*, 6, 1233.

Dutta, P., Singha, A. K., Das, P., & Kalita, S. (2011). Management of brinjal fruit and shoot borer, *Leucinodes orbanalis* Guenee in agro-ecological condition of West Tripura. *Scholarly journal of Agricultural Science*, *1*(2), 16-19.

FAO. 2019. Compare Data. Retrieved January 30, 2021, from FAOSTAT: http://www.fao.org/faostat/en/#compare

Gangopadhyay, C., Maity, T. K., & Mandal, S. K. (1996). Screening of brinjal germplasms against fruit and shoot borer *Leucinodes orbonalis* Guen. *Environment and Ecology*, *14*(4), 834-836.

Ghimire, A., & Khatiwada, B. P. (2001). Use of pesticides in commercial vegetable cultivation in Tandi, Eastern Chitwan, Nepal. *Survey report submitted to Department of Entomology Institute of Agricultural and Animal Science (IAAS), Rampur, Chitwan, Nepal, 10.*

Ghosh, S. K., & Senapati, S. K. (2009). Seasonal fluctuation in the population of *Leucinodes orbonalis* Guen. in the sub-himalayan region of West Bengal, India and its control on eggplant (*Solanum melongena* L.). *Precision agriculture*, *10*(5), 443-449.

Gomez, K. A., & Gomez, A. A. (1984). *Statistical procedures for agricultural research*. John wiley & sons. 8-13.

Goud, G. S., Bondre, C. M., & Gawali, K. A. (2019). Efficacy of some chemical and botanical pesticides against brinjal shoot and fruit borer *Leucinodes orbonalis* Guenee. *Journal of Pharmacognosy and Phytochemistry*, *8*(4), 2453-2455.

Gupta, H. C. L., Mehta, S. C., & Pareek, B. L. (1989). Effectiveness of aldicurb against insect pests of brinjal along with its uptake and residues. *Annals of Arid Zone*, 28(3-4), 309-314.

Hanson, P. M., Yang, R. Y., Tsou, S. C., Ledesma, D., Engle, L., & Lee, T. C. (2006). Diversity in eggplant (*Solanum melongena*) for superoxide scavenging activity, total phenolics, and ascorbic acid. *Journal of Food composition and Analysis*, 19(6-7), 594-600.

Hossain, M. M., Shahjahan, M., & Bari, M. N. (2002). Chlorophyll contents of brinjal plants influencing the resistance and susceptibility to brinjal shoot and fruit borer, *Leucinodes orbonalis* guenee (No. RESEARCH).

Hossain, M. M., Shahjahan, M., Prodhan, A. K. M. A., Islam, M. S., & Begum, M. A. (2002). *Study of anatomical characters in relation to resistance against brinjal shoot and fruit borer* (No. RESEARCH).

Hossain, Q. K., & Hossain, M. (2016). Relative abundance of different insect pests and their natural enemies in brinjal ecosystem. *Bangladesh j. entomol*, 26(1), 59-70.

Jai, K. L., Pareek, B. L., & Swaroop, S. (2002). Seasonal incidence of shoot and fruit borer (Leucinodes orbonalis Guen.) on eggplant (*Solanum melongena* L.) in Rajasthan. *Annals of Biology*, 18(2), 165-169.

Jat, K. L. (2003). Biophisical and biochemical factor of resistance in brinjal against *Leucinodes orbanalis* Guen. *Indian Journal of Entomology*, 65(2): 252-259.

Javed, H., Mohsin, A., Aslam, M., Naeem, M., Amjad, M., & Mahmood, T. (2011). Relationship between morphological characters of different aubergine cultivars and fruit infestation by *Leucinodes orbonalis* Guenee. *Pak. J. Bot*, *43*(4), 2023-2028.

Jayakrishnan, S., & Madhuban, G. (2012). Evaluation of synthetic and natural insecticides for the management of insect pest control of eggplant (*Solanum melongena* L.) and pesticide residue dissipation pattern. *American Journal of Plant Sciences, 2012.*

Jayaraj, J. and Manisegaran, S. (2010). Management of fruit and shoot borer in brinjal. The Hindu Sci-Tech. Agri. College and Res. Inst. Madurai.

Kalloo, G. (1993). Eggplant: *Solanum melongena* L. *Genetic improvement of vegetable crops*, 587-604.

Kar, D., Kuanar, A., Ray, A., Gaur, M., Pattanaik, B., & Mishra, B. (2021). Genetic diversity of Brinjal fruit and shoot borer (BSFB) population of Odisha, India. *Iranian Journal of Science and Technology, Transactions A: Science*, *45*(1), 135-144.

Karim, A. N. M. R. (2004, October). IPM for vegetable crops: issues and technology developments in Bangladesh. In *A keynote paper presented at the sixth biennial conference of Bangladesh Entomological Society held at BARI, Joydebpur, Gazipur, Bangladesh.*

Khanzada, K. K., Khanzada, B., Chandio, R. H., Sipio, F. A., Jamali, F. H., & Shah, S. A. (2018). Bio-efficacy of newer insecticides against shoot and fruit borer, *Leucinodes orbonalis* (L.) Guen. on brinjal.

Khorsheduzzaman, A. K. M., Alam, M. Z., Rahman, M. M., Mian, M. K., & Mian, M. I. H. (2010). Biochemical basis of resistance in eggplant (*Solanum melongena* L.) to *Leucinodes orbonalis* Guenee and their correlation with shoot and fruit infestation. *Bangladesh Journal of Agricultural Research*, 35(1), 149-155.

Krishna, T. M., Lal, O. P., & Srivastava, Y. N. (2001). Extent of Losses caused by shoot and fruit borer, *Leucinodes orbonalis* Guen., to promising varieties of brinjal, *Solanum melongena* L. *Journal of Entomological Research*, *25*(3), 205-212.

Kumar, A., & Shukla, A. (2002). Varietal preference of fruit and shoot borer, *Leucinodes orbonalis* Guen. on brinjal. *Insect environment,* 8(1), 44.

Kumar, N. K. K., & Sadashiva, A. T. (2009). Solanum macrocarpon: a wild species of brinjal resistant to brinjal shoot and fruit borer, Leucinodes orbonalis (Guen.). *Insect Environment*, *2*(2), 41-42.

Lalita, S., & Kashyap, L. (2020). Biology and mechanisms of resistance to brinjal shoot and fruit borer: A review. *Journal of Entomology and Zoology Studies*, *8*(2), 2111-2118.

Latif, M. A., Rahman, M. M., & Alam, M. Z. (2010). Efficacy of nine insecticides against shoot and fruit borer, *Leucinodes orbonalis* Guenee (Lepidoptera: Pyralidae) in eggplant. *Journal of pest science*, *83*(4), 391-397.

Mainali, R. P. (2012). Bio-rational management of eggplant fruit and shoot borer, *Leucinodes orbonalis* Guenee, (Lepidoptera: Pyralidae) in Nepal. M. Sc. Ag. Thesis. Institute of Agriculture and Animal Sciences/TU, Chitwan, Nepal. 109.

Mainali, R. P., Thapa, R. B., Pokhrel, P., Dangi, N., & Aryal, S. (2013). Bio-rational management of eggplant fruit and shoot borer, *Leucinodes orbonalis* Guenee,(Lepidoptera: Pyralidae) in Lalitpur, Nepal. *Journal of Plant Protection Society*, *4*, 235-247.

Mathur, A., Singh, N. P., & Swaroop, S. (2012). Management of brinjal shoot and fruit borer: Dilemma of adopting Bt brinjal over Integrated Pest Management technology. In *Proceedings of International Conference on Clean and Green Energy, Singapore IPCBEE*, 27, 93-97.

Mathur, A., Singh, S., Singh, N. P., & Meena, M. (2012). Field evaluation of plant products and microbial formulations against brinjal shoot and fruit borer, *Leucinodes orbonalis* Guenee under semi-arid conditions of Rajasthan. *Journal of Biopesticides*, *5*(1), 71.

Mochiah, M. B., Banful, B., Fening, K. N., Amoabeng, B. W., Offei Bonsu, K., Ekyem, S., & Owusu-Akyaw, M. (2011). Botanicals for the management of insect pests in organic vegetable production. *Journal of Entomology and Nematology*. 85-97.

Murali, S., Jalali, S. K., Kariyanna, B., Shylesha, A. N., Shivalinga Swamy, T. M., & Gandhi Gracy, R. (2017). Effect of releases of *T. chilonis*, application of cypermethrin and their combination against brinjal shoot and fruit borer, *Leucinodes orbonalis* Guenée (Lepidoptera: Crambidae). *Journal of Entomology and Zoology Studies*, *5*(5), 1462-1469.

Murali, S., Jalali, S. K., Shylesha, A. N., Swamy, T. S., & Gracy, R. G. (2017). Documentation of Pyrethroid Resistance against Brinjal Shoot and Fruit Borer, *Leucinodes orbonalis* Guenee (Pyralidae: Lepidoptera). *Int. J. Curr. Microbiol. App. Sci*, *6*(8), 3260-3270.

Murugesan, N., & Murugesh, T. (2009). Bioefficacy of some plant products against brinjal fruit borer, *Leucinodes orbonalis* Guenee (Lepidoptera: Pyrallidae). *Journal of Biopesticides*, *2*(1), 60-63.

Naeem, M. Y., & Ugur, S. (2019). Nutritional content and health benefits of eggplant. *Turkish Journal of Agriculture-Food Science and Technology*, *7*(sp3), 31-36.

NARC (2000). A Research project for management of eggplant fruit and shoot borer using IPM approach. Entomology Division, Nepal Agricultural Research Council, Khumaltar, Lalitpur, Nepal.

Neupane, F. P. (2000). Integrated management of vegetable pest (Nepali language). *Centre for Environmental and Agricultural Policy Research Extension and Development (CEAPRED), Bakhundol, Lalitpur, Nepal*, 172.

Niño-Medina, G. U. I. L. L. E. R. M. O., Urías-Orona, V. A. N. I. A., Muy-Rangel, M. D., & Heredia, J. B. (2017). Structure and content of phenolics in eggplant (*Solanum melongena*)-a review. *South African Journal of Botany*, 111, 161-169.

Prabhu, M., Natarajan, S., & Pugalendhi, L. (2007). Biochemical basis of shoot and fruit borer (*Leucinodes orbonalis* G.) resistance in brinjal (*Solanum melongena* L.). In Recent trends in horticultural biotechnology, Vol. II. ICAR national symposium on biotechnological interventions for improvement of horticultural crops: issues and strategies, Vellanikkara, Kerala, India, 10-12 January, 2005 (829-836). New India Publishing Agency.

Prakash, A., Rao, J., & Nandagopal, V. (2008). Future of botanical pesticides in rice, wheat, pulses and vegetables pest management. *Journal of Biopesticides*, *1*(2), 154-169.

Prasad, T. V., Bhardwaj, R., Gangopadhyay, K. K., Arivalagan, M., Bag, M. K., Meena, B. L., & Dutta, M. (2014). Biophysical and biochemical basis of resistance to fruit and shoot borer (*Leucinodes orbonalis* Guennee) in eggplant. *Indian Journal of Horticulture*, 71(1), 67-71.

Preneetha, S. (2002). Breeding for shoot and fruit borer (Leuclnodes orbonalis Guenee) resistance in brinjal (*Solanum melongena* L.) (Doctoral dissertation, Tamil Nadu Agricultural University).

Prodhan, M.D.H., M. Shahjahan and M.A.R Choudhury. (2009). Moistutre content of brinjal shoot and fruit borer and its relation to brinjal shoot and fruit borer infestation. *Bangladesh J. entomol*. 19(2): 83-89.

Rahman, M. M., Ali, M. R., & Hossain, M. S. (2009). Evaluation of combined management options for managing brinjal shoot and fruit borer. *Academic Journal of Entomology*, *2*(2), 92-98.

Raigón, M. D., Prohens, J., Muñoz-Falcón, J. E., & Nuez, F. (2008). Comparison of eggplant landraces and commercial varieties for fruit content of phenolics, minerals, dry matter and protein. *Journal of food composition and analysis*, *21*(5), 370-376.

Rashid, M.M. 1999. Begun Paribarer Shabji. pp. 137 -154. In: Shabji Biggan (in Bangla). 1st ed. Bangla Academy, Dhaka, Bangladesh. 515.

Rishi, P., Vikrant, S. D., Sanjeev, S., & Sanjeev, K. (2018). Screening of some brinjal germplasm line against brinjal shoot and fruit borer *Leucinodes orbanalis* guenee in central (UP).

Sardana, H.P., Arora, S., Singh, D.K., Kadu, L.N. (2004). Development and validation of adaptable Integrated Pest Management in eggplant, *Solanum melongena* L. in a farmer's participatory approach. *Indian Journal of Plant Protection*. 2004; 32:123-128.

Schippers, R. R. (2000). *African indigenous vegetables: an overview of the cultivated species*.

Sen, K., Samanta, A., Alam, S. F., Dhar, P. P., & Samanta, A. (2017). Field Evaluation of a New Ready Mix Formulation Ampligo 150 ZC (Chlorantraniliprole 9.3%+ Lambda Cyhalothrin 4.6% ZC) against Shoot and Fruit Borer (*Leucinodes orbonalis* Guen.) infestation in Brinjal. *Journal of Pharmacognosy and Phytochemistry*, *6*(5), 1674-1678.

Sharma, D. R. (2002). Bioefficacy of certain insecticide and biopesticides against major pest of brinjal under field condition. *M. Sc.(Ag.) Thesis, Indian Agriculture Research Institute, New Delhi, India, 160*.

Shaukat, M. A., Ahmad, A., & Mustafa, F. (2018). Evaluation of resistance in brinjal (*Solanum melongena* L.) against brinjal shoot and fruit borer (*Leucinodes orbonalis* Guen.) infestation: A review. *International Journal of Applied Sciences and Biotechnology*, *6*(3), 199-206.

Shinde, K. G. (2007). Correlation of physical and chemical characters in brinjal in relation to shoot and fruit borer infestation. *Advances in Plant Sciences*, 20(2), 613.

Shukla, A., & Khatri, S. N. (2010). Incidence and abundance of brinjal shoot and fruit borer *Leucinodes orbonalis* Guenee. *The Bioscan*, *5*(2), 305-308.

Singh, B. D. (1983). Breeding for Resistance to Biotic Stresses II. Insect Resistance In: Plant Breeding Principles and Methods. Ludhiana, India. 494.

Singh, R., Bhatnagar, A., & Singh, D. V. (2015). Efficacy of different doses in combination of chlorantraniliprole and lambda cyhalothrin against pests of Brinjal. *Annals of Plant Protection Sciences*, *23*(1), 59-61.

Singh, Y. P., & Singh, P. P. (2001). Screening of Brinjal (*Solanum melongena* L.) cultivars against shoot and fruit borer (*Leucinodes orbonalis* Guen.) at medium high altitude hills of Meghalaya. *Indian Journal of Plant Protection*, *29*(1/2), 34-38.

Srinivasan, R. (2012). Integrating biopesticides in pest management strategies for tropical vegetable production. *Journal of biopesticides*, *5*, 36.

Stommel, J. R., Whitaker, B. D., Haynes, K. G., & Prohens, J. (2015). Genotype× environment interactions in eggplant for fruit phenolic acid content. *Euphytica*, *205*(3), 823-836.

Subbaratnam, G. V., & Butani, D. K. (1981). *Screening of eggplant varieties for resistance to insect pest complex* (No. RESEARCH). *Vegetable Sci.,* 8: 149-153.

Talekar, N. S. (2002). Controlling brinjal fruit and shoot borer: A simple, safe and economical approach. International Cooperators' Guide, AVRDC Pub. #02-534. Asian Vegetable Research and Development Center, Shanhua, Taiwan. 4.

Taylo, L. D., Sison, M. L. J., & Hautea, D. M. (2016). Use of artificial infestation for field bioefficacy assessment of Bt eggplant against the eggplant fruit and shoot borer, *Leucinodes orbonalis* Guenee (Lepidoptera: Crambidae). *Philippine Agricultural Scientist*, *99*(1), 119-126.

Toppino, L., Prohens, J., Rotino, G. L., Plazas, M., Parisi, M., Carrizo García, C., & Tripodi, P. (2021). Pepper and eggplant genetic resources. In *The Wild Solanums Genomes* (pp. 119-154). Springer, Cham.

Vinod, S., Ramesh, L., & Anil, C. (2001). Screening of brinjal (*Solanum spp.)* germplasm against shoot and fruit borer, *Leucinodes orbonalis* Guen. *Insect Environment*, *7*(3), 126-127.