# BIO-RATIONAL MANAGEMENT PRACTICES INCLUDING BIO-CONTROL AGENTS AGAINST BRINJAL SHOOT AND FRUIT BORER, *LEUCINODES ORBONALIS*

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## CERTIFICATE

This is to certify that the thesis entitled **'BIO-RATIONAL MANAGEMENT PRACTICES INCLUDING BIO-CONTROL AGENTS AGAINST BRINJAL SHOOT AND FRUIT BORER, *LEUCINODES ORBONALIS*'** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **Master of Science in Entomology,** embodies the result of a piece of *bonafide* research work carried out by **MD. JANNATUL NAYEEM, Registration number: 13-05495** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: June, 2020
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*Dedicated*

*To*

*My Beloved Parents*

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## ABSTRACT

The present experiment was conducted at the experimental field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh to find out the efficacy of bio-rational management practices including bio-control agents against Brinjal Shoot and Fruit Borer (BSFB) during October, 2018 to March, 2019. This experiment tested on a Hybrid brinjal variety "Begun-706" laid out in RCBD with 3 replications. The experiment comprised eight treatments *viz.*, $T_1$= Cultural + mechanical control method, $T_2$= Braconid wasps @ 20-25/plot + sanitation, $T_3$= Sanitation + Funnel Pheromone trap, $T_4$= Sanitation + Sevin 50 WP @ 1.0g/L of water, $T_5$= Success 2.5 EC @ 0.5 ml/L of water + Pheromone trap, $T_6$= Spinosad 45% SC @ 0.01% + Funnel Pheromone trap, $T_7$= Sanitation + *Trichogramma evanescens* @ 1 card/plot (1000 eggs per card) and $T_8$= Untreated control. The plots treated with $T_5$ treatment, resulted significantly lowest percentage of infested shoot, flower and fruit, which was statistically similar with $T_6$ treatment during the whole period and the highest infestation was found in $T_8$ treatment followed by $T_1$ treatment. The yield contributing characters found highest in $T_5$ treatment for length, girth and weight of individual fruit and was statistically similar to $T_6$ treatment. In case of yield, $T_5$ (56.65 t $ha^{-1}$) showed the best result which was statistically similar with $T_6$ (53.88 t $ha^{-1}$) followed by $T_4$ (28.45 t $ha^{-1}$), $T_7$ (27.43 t $ha^{-1}$), $T_2$ (25.10 t $ha^{-1}$), $T_3$ (24.02 t $ha^{-1}$) and the lowest result was found in $T_8$ (23.66 t $ha^{-1}$) followed by $T_1$ (33.20 t $ha^{-1}$). Percent increase over control was higher in $T_5$ (139.42%), statistically similar with $T_6$ (127.73%). Therefore, $T_5$ and $T_6$ exhibited more than two times higher yield than $T_8$. From this study, it was concluded that $T_5$ (Success 2.5 EC @ 0.5 ml/L of water + Pheromone trap) was the most viable bio-rational options for *L. orbonalis* management which was statistically similar with $T_6$ (Spinosad 45% SC @ 0.01% + Funnel Pheromone trap).

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# LIST OF ACRONYMS

| | | |
|---|---|---|
| AEZ | = | Agro-Ecological Zone |
| BARI | = | Bangladesh Agricultural Research Institute |
| CV% | = | Percentage of coefficient of variance |
| RCBD | = | Randomized Complete Block Design |
| DAT | = | Days after transplanting |
| @ | = | At the rate of |
| *et al.* | = | And others |
| i.e., | = | *id est* (L), that is |
| LSD | = | Least Significant Difference |
| MP | = | Muriate of Potash |
| No. | = | Number |
| NS | = | Non-significant |
| SAU | = | Sher-e-Bangla Agricultural University |
| SRDI | = | Soil Resources and Development Institute |
| TSP | = | Triple Super Phosphate |
| viz., | = | Videlicet (namely) |
| wt. | = | Weight |
| BARC | = | Bangladesh Agricultural Research Council |
| °C | = | Degree Centigrade |

# CHAPTER I

# INTRODUCTION

Brinjal (*Solanum melongena* L.) is one of the widely used vegetable crops by most of the people and is popular in many countries. It is also known as eggplant or aubergine belonging to the family "Solanaceae". It is adapted to a wide range of climatic conditions, such as high rainfall and high temperatures from North to South and West to East. Having a hot-wet climate (Hanson *et al.,* 2006), it is one of the most important vegetables in South and South-East Asia (Thapa, 2010). The cultivation of eggplant is more than 1,600,000 ha producing around 50 million Mt throughout the world, among which 90% of production from five countries, of which china shares 58% of output, India 25%, followed by Iran, Egypt and Turkey (FAO, 2012).

Due to its nutritive value, consisting of minerals like iron, phosphorous, calcium and vitamins like A, B and C, unripe fruits are used primarily as a vegetable in the country. It is also used as a raw material in pickle making (Singh *et al.,* 1963) and as an excellent remedy for those suffering from liver complaints. It is used in Ayurvedic medicine for curing diabetes. It is also used as a good appetizer. It is a good aphrodisiac, cardiotonic, laxative and reliever of inflammation. Also, the higher yield and longer fruiting and harvesting period lure the farmers on eggplant production (Ghimire *et al.,* 2001).

However, eggplant production is in threat in recent years due to the increased cost of production on the management of insect pests. Insect pest infestation is one the major constraints for commercial production in all brinjal growing areas. Generally, brinjal is attacked by many insects such as brinjal shoot and fruit borer, leafhopper, whitefly, thrips, aphid, spotted beetles, leaf roller, stem borer and blister beetle. About 27 insect pests were recorded in an experimental area that infests the brinjal crop (Singh *et al.,* 2002). Among all the insect pests brinjal shoot and fruit borer, *Leucinodes orbonalis* Guenee is the key pest of eggplant (Saimandir and Gopal, 2012) inflicting sizeable damage in almost all the eggplant growing areas (Dutta *et al.,* 2011) and is most destructive, especially in South Asia (Thapa, 2010). This pest is active in moderate climates throughout the year. The females lay approximately 250 eggs one by one on developing fruits and young shoots of eggplant. The caterpillar is pink in color and is covered with sparsely distributed hairs all over the body. Fully grown larva measures about 20 mm long and pupates in a tough silken cocoon. The entire life cycle is completed in 3-6 weeks. There are five overlapping generations of the pest in a year. Severe damage to fruits and shoots is caused by the larvae of the pest. The petioles, midribs of large leaves and young tender shoots are bored by newly hatched larvae. Due to larval activity, the translocation of nutrients towards shoots is affected. This causes withering and drooping of shoots, resultantly the growth of eggplant and size and number of fruits are significantly reduced (Atwal and Dhaliwal, 2007). As a result of its making tunnel and feeding inside young fruit which afterward clogged with frass, the fruits become unmarketable and the yield loss due to the pest is to the extent of 70-92 percent (Reddy and Srinivas, 2004). It is also reported that there will be reduction in vitamin C content to an extent of 68% in the infested fruits (Hemi, 1955). Hence, many farmers are leaving growing eggplant because of this pest (Gapud and Canapi, 1994).

Although insecticidal control is one of the common means against the fruit borer, many of the insecticides applied are not effective in the satisfactory control of this pest. Brinjal being a vegetable crop, the use of chemical insecticides will leave considerable toxic residues on the fruits. Besides this, sole dependence on insecticides for the control of this pest has led to insecticidal resistance by the pest (Natekar *et al.*, 1987). The indiscriminate use of pesticides also leads to environmental pollution and disruption of natural enemies. According to Alam *et al.* (2003), the non-judicious use of insecticides may result in a series of problems related to both loss of their effectiveness and in the long run, it develops insect resistance. In the case of residual toxicity of pesticides in brinjal is another big constraint to our vegetable exports in the foreign markets (Islam *et al.*, 1999). A shift from chemical approach is the urgent need by practicing alternative strategies for the management of problematic pests like *L. orbonalis.* Development of eco-friendly approaches will provide safety to natural enemies and result in quality products without any insecticidal residues. In recent years, the use of egg parasitoids, pheromone traps started gaining importance as effective tools in pest management. Use of bio-control agents is a safe and non-hazardous tactic for the management of insect pests (Hassan, 1994). Among this, *Trichogramma* sp. egg parasitoid was successfully employed for crop protection (Hassan, 1992). Neem cake and azadirachtin formulations affect brood emergence and level of pest population in the field. It is thus immense need to find out the contribution of bio-rational based management practices including bio-control agents (parasitoids) to control brinjal shoot and fruit borer to secure the production of brinjal of the country.

In Bangladesh, farmers solely rely on chemical pesticides for their welfare against this obnoxious insect pest and fail in most of the cases and damage the ecological balance. There is tremendous misuse of insecticides in an attempt to produce damage-free marketable fruits (Srinivasan, 2009). The application of insecticide, however, can cause several problems such as development of insecticide resistance pest insects, induction of resurgence of target pests, outbreak of secondary pests and undesirable effect on non-target organisms as well as serious environment pollution. Insecticide residues can exist in fruit which causes health hazards to consumers. Considering the hazardous impact of chemical pesticides on non-target organisms as well as environment, this study was undertaken to assess the losses caused by brinjal shoot and fruit borer, *L. orbonalis;* efficacy of different management practices to get rid of this pest and aiming at the development of eco-friendly and sustainable pest management system in brinjal so that farmer can get satisfactory yield as well as consumer can get nontoxic fresh brinjal.

**Objectives of the Research Work:**

- To assess the damage potentiality of brinjal shoot and fruit borer, *Leucinodes orbonalis* on the host.
- To find out the efficiency of the different management practices against brinjal shoot and fruit borer, *L. orbonalis* in brinjal.
- To highlight the establishment of an environmentally safe control measure of brinjal vegetable which help to reduce the use of chemical pesticides.

# CHAPTER II

# REVIEW OF LITERATURE

Eggplant (US, Australia, New Zealand, anglophone Canada), aubergine (UK, Ireland, Quebec) or brinjal (South Asia, South Africa) is a plant species in the nightshade family Solanaceae. *Solanum melongena* is grown worldwide for its edible fruit. In 2018, China and India combined accounted for 87% of the world production of eggplants. Brinjal shoot and fruit borer (BSFB) is the most pernicious pest of brinjal. For controlling brinjal shoot and fruit borer, it is necessary to have a concept of the systematic position, origin and distribution, pest status and host range, nature of damage, seasonal abundance and life cycle. Farmers mainly control BSFB through the use of different chemicals. But the concept of management of pest employing bio-rational materials gained momentum as mankind become more conscious about the environment. Bio-ratrional based management is the recent and eco-friendly approaches for pest control. Information related to the management of BSFB using bio-ratrional based management is very scanty. Though, some of the important and informative works and research findings related to the control of BSFB through bio-ratrional based management so far been done at home and abroad have been reviewed in this chapter under following sub-headings:

## 2.1 Systematic Position of Brinjal Shoot and Fruit Borer (BSFB)

Phylum: Arthropoda

Subphylum: Uniramia

Class: Insecta

Order: Lepidoptera

Family: Crambidae

Genus: *Leucinodes*

Species: *Leucinodes orbonalis*

## 2.2 Origin and Distribution of Brinjal Shoot and Fruit Borer

*Leucinodes orbonalis* Guenee, the eggplant shoot and fruit borer, is a species of moth that was first described from specimens from India and Java (Guenee, 1854). According to current knowledge, it is widely distributed in tropical and subtropical Asia (CABI, 2012) and sub-Saharan Africa (Walker, 1859; Frempong, 1979; CABI, 2012). The larvae are pests of Solanaceae, especially *Solanum melongena* L. (aubergine, eggplant or brinjal) fruits and stems where they feed internally. Their infestation can substantially reduce yields from aubergine cultivation, and yield losses of more than 65% have been recorded from Asia (EPPO, 2008).

Mally *et al.* (2015) pointed out that the larvae of the old world genera *Leucinodes* Guenee, 1854 and *Sceliodes* Guenee, 1854 are internal feeders in the fruits of Solanaceae, causing economic damage to cultivated plants like *Solanum melongena* and *S. aethiopicum*. In sub-Saharan Africa, five nominal species of *Leucinodes* and one of *Sceliodes* occur. One of these species, the eggplant fruit and shoot borer *L. orbonalis* Guenée, 1854, is regarded as regularly intercepted from Africa and Asia in Europe, North and South America and is therefore a quarantine pest on these continents. The results suggest that both genera are congeneric, with *Sceliodes* syn. established as junior subjective synonym of *Leucinodes*. *L. orbonalis* is described from Asia and none of the samples investigated from Africa belong to this species.

The larvae are commonly moved in international trade with plants and fruits, as their internal feeding and the resulting damage may not be visible during pre-export inspections. Thus, *Leucinodes orbonalis* is a quarantine pest of concern to a number of countries outside its native range (Mally *et al.*, 2015). This includes the member countries of the European and Mediterranean Plant Protection Organisation (EPPO), where it was recommended as an addition to the alert list of pests in 2008 (EPPO, 2008), and in 2012 transferred to the A1 list of pests recommended for statutory regulation (EPPO, 2012). It is an A1 pest for several South American countries including Uruguay and Argentina and has repeatedly been intercepted in the USA (Whittle and Ferguson, 1987; Solis, 1999).

Until recently, all pyraloid larvae damaging Solanaceae fruits in Asia and Africa and intercepted from imports to Europe have been regarded as two species, *Leucinodes orbonalis* and *Sceliodes laisalis* (Walker, 1859). Hayden *et al.* (2013) and Gilligan and Passoa (2014) pointed out that *Leucinodes orbonalis* is restricted to Asia and that there are "three species in the *L. orbonalis* complex in Africa that are not conspecific with the Asian species.

*Leucinodes orbonalis* was found in India, Indonesia: Java (Guenee, 1854), Sri Lanka (Walker, 1859; Moore, 1885), Myanmar (Burma), Andaman Islands (Pagenstecher, 1900), Bangladesh, Brunei, Cambodia, China, Japan, Laos, Malaysia, Nepal, Pakistan, Philippines, Singapore, Taiwan, Thailand, Vietnam (CABI, 2012), Australia (Shaffer *et al.*, 1996) imported to Great Britain, the Netherlands, Denmark and the U.S.A. (Boateng *et al.*, 2005).

### 2.3 Pest Status and Host Range of BSFB

Gangwar *et al.* (2014) conducted an experiment during Kharif, 2011 at Crop Research Centre (CRC) of Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut (U.P.). During the studies on the insect-pests succession revealed that a total of eight insect species were found associated with brinjal crop at different crop growth stages. The first attack on the crop appeared in the one week after transplantation and continued till crop harvested. Pests were found attacking the crop were jassids (*Amrasca biguttula biguttula*), aphids (*Aphis gossypii),* white fly (*Bemisia tabaci*), leaf roller (*Eublemma olivacae*), shoot and fruit borer (*Leucinodes orbonalis*), epilachna beetle (*Epilachna vigintioctopunctata*), leaf webber (*Psara bipunctalis*) and grass hopper (*Chrotogonus* spp.). Among them, brinjal shoot and fruit borer (*L. orbonalis)* was recorded as major pest. Jassids (*A. biguttulabiguttula* Ishida), aphid (*A. gossypii* Glov.) and epilachna beetle (*E. viginitioctopunctata* F.) were found to damage the crop moderately.

Devi *et al.* (2014) stated that brinjal or eggplant (*Solanum melongena* L.) is an important solanaceous crop. The brinjal is of much importance in the warm areas of East, being grown extensively in India, Bangladesh, Pakistan, China and the

Philippines. It is also popular in Egypt, France, Italy and United States. In India, it is one of the most common, popular and principal vegetable crops grown throughout the country except higher altitudes. The area under brinjal cultivation in the world was 1.72 million hectares with a total production of 43.17 million metric tonnes having a productivity of 25.0 metric tonnes per hectare in 2010-11. The shoot and fruit borer, *Leucinodes orbonalis* Guenee is the most destructive pest of brinjal causing damage to the brinjal plant from early stage to fruit stage. The larvae tunnels insides the tender fruits and make them totally unfit for human consumption. The pest caused 52% to 74% damage.

Shoot and fruit borer is the most destructive insect pest of brinjal (Alam, 1969; Butani and Jotwani, 1984; Nair, 1986; Chattopadhyay, 1987). It can also infest potato, peas and tomato (Hill, 1985). Isahaque and Chaudhuri (1983) recorded that the alternate hosts of brinjal shoot and fruit borer were *Solanum nigrum, S. indicum, S. torvum, S. myriacanthum* and *S. tuberosum*.

### 2.4 Life Cycle of BSFB

Taley *et al.* (1984) carried out an experiment about the bionomics of brinjal shoot and fruit borer, *Leucinodes orbonalis* Guen. during the year 1975-76. A single female laid 150 to 215 eggs. The maximum numbers of eggs were laid on the upper and lower surfaces of leaves i.e. 39.34% and 44.39%, respectively. The incubation period lasted from 3 to 6 days. The larval period varied from 10 to 20 days. The pupal period lasted for 7 to 12 days. The total life cycle occupied from egg to adult stage was 23-35 days. The sex ratio (Male to Female) was 1:2. About 8 to 9 generations were observed in a year.

#### 2.4.1 Eggs

Oviposition happens amid the night and eggs are laid independently on the lower surface of the young leaves, green stems, bloom buds, or calyces. Eggs are laid by a female in shift ranging from 80 to 253 (Taley *et al.*, 1984; Alpuerto, 1994) and as high as 260 in number (FAO, 2003). The eggs are laid in the early hours of the mornings separately or in bunches on the ventral surface of the leaves (CABI, 2007). They are straightened, curved with 0.5 mm in distance across and shading is smooth white yet change to red before bring forth (Alam *et al.*, 2006). The egg takes brooding time of 3-5 days in summer and 7-8 days in winter and hatch into dull white larvae (Rahman, 2006).

Alam *et al.* (1982) and Kavitha *et al*. (2008) found that a single female could lay 5 to 242 eggs in her life time. Eggs were laid mostly singly and sometimes in the batches of 2 to 4 eggs. Females preferred to lay eggs on the lower surface of the tender leaves or the twigs of plant, flowers, calycies of the fruits. Eggs were oval or somewhat elongated in shape and creamy white in colour which changed to orange with prominent black spot before hatching (Harit and Shukla, 2005; Singh and Singh, 2001). The pre-oviposition, oviposition and post-oviposition period viz., 1.1 to 2.1 days, 1.4 to 4.0 days and 1.0 to 2.0 days, respectively had been reported by Ali and Sanghi (1962); Jat *et al.* (2003); Mehto *et al.* (1983); Raina and Yadav (2017) and Singh and Singh (2001). Whereas, incubation period was recorded as 3 to 4 days by Ali and Sanghi (1962); Alam *et al.* (1982); Lall and Ahmed (1965) and Muthukumaran and Kathirvelu (2007). However, Raina and Yadav (2017) found that maximum hatching (38.2%) occurred on third day after oviposition followed by 27.0 and 0.6 per cent on fourth and fifth days, respectively.

### 2.4.2 Larvae

The larval period keeps going 12-15 days amid summer and 14-22 days amid winter season (Rahman *et al.*, 2009). Larvae go through no less than five instars (Atwal, 1976) and there are reports of the presence of six larval instars (Baang and Corey, 1991; FAO, 2003). Sandanayake and Edirisinghe (1992) contemplated the larval conveyance on develop eggplant. They discovered first instars in bloom buds and blossoms, second instar in all susceptible plant parts, third and fourth instar in shoots and for the most part in fruits. Usually, the extent of the main instar larvae is under 1 mm long, the last instar larvae is 15-18 mm long. However, Sandanayeke and Edirinsinge (1992) announced the span of last instar larvae to be 18 to 23 mm. One fruit contains up to 20 larvae in Ghana (Frempong, 1979).

According to Jat *et al.* (2003), Harit and Shukla (2005), Patial *et al.* (2007), Raina and Yadav (2017) and Singh and Singh (2001), larvae passed through five instars before entering the pupal stage. They observed average duration of 1st, 2nd, 3rd, 4th and 5th larval instars *viz.*, 1-2, 2-3, 2-3, 2-4 and 2-4 days, respectively. Newly hatched larva was tiny, creamy or dirty white in colour with a prominent dark brown or light black head, three pairs of thoracic legs and five pairs of prolegs. Second instar larvae resembled the first instar larvae except larger in size and slightly darker colour. The third instar larvae were much longer and darker than the preceding instars, in which prothoracic shield had distinct markings, thoracic legs were dark brown in colour. Fourth instar was slightly pinkish in colour. Fifth instar was cylindrical in shape and pinkish brown in colour having three distict segments of thorax and five pairs of well developed prolegs. But, Alam *et al.* (1982) and Saxena (1965) recorded six larval instars of shoot and fruit borer. Das and Patnaik (1970) and Jat *et al.* (2003) also reported that average larval period lasted for 12.3 to 14.0 days.

### 2.4.3 Pupae

The full-developed larvae leave the infested shoots and pupate in the dried shoots and leaves or in plant refuse and debris fallen on the ground inside intense luxurious covers. There were confirmations of quality of cases at soil profundities of 1 to 3 cm (Alam *et al.*, 2003). They pupate at first glance they touch first (FAO, 2003). The pupal period keeps going 6 to 17 days contingent on temperature (Alam *et al.*, 2003). It is 7-10 days amid summer, while it is 13-15 days amid winter season (Rahman, 2006). The shading and surface of the case coordinates the surroundings making it hard to distinguish.

Butani and Verma (1976) and Mehto *et al.* (1983) reported that pupal period varying from 7 to 10 days. They observed that pupae were dark brown in colour with wider cephalic lobe and narrow anal end with eight hook shaped fine spines at the posterior end of abdomen. Pupation took place on glass jars, soil, muslin cloth, on the fruits and sometimes on the leaves of plant (Alam *et al.*, 1982; Jat *et al.*, 2003 and Mathur and Jain, 2006). Whereas, according to Raina and Yadav (2017), pupal period varied between 6 to 8 days. They did not observe adult emergence upto 5$^{th}$ day after pupation. The emergence of adult started on 6$^{th}$ day after pupation and continued upto the 8$^{th}$ day. On an average, 14 percent, 30 percent and 10 per cent adults emerged on 6th, 7th and 8th day after pupation, respectfully and maximum emergence was observed on 7th day. Mean adult emergence was found to be 54 percent.

### 2.4.4 Adult

The adult was a little white moth with 40-sectioned radio wires (Sexena, 1965) and having spots on forewings of 20 to 22 mm spread. Emerging adults were generally found on the lower leaf surfaces following development or covering up under the leaves inside the plant extension (Alam *et al.*, 2003). A mid day, they liked to stow away in close-by shady plots however around evening time every real movement, such as bolstering, mating and finding a place for egg-laying occur (FAO, 2003). The adult increased full development in 10 to 14 days. Life span of adults kept going 1.5 to 2.4 days for males and 2.0 to 3.9 days for females. The pre-oviposition and oviposition periods extended 1.2 to 2.1 and 1.4 to 2.9 days, respectfully (Mehto *et al.*, 1981). The adult male passed on in the wake of mating and the female moth bites the dust in the wake of laying eggs (Kar *et al.*, 1995). The general life cycle finished in 22 to 55 days. It gave rise five ages per year and was dynamic consistently. FAO (2003) demonstrated the impact of climatic conditions in the life cycle of the *L. orbonalis* in eggplant. *L. orbonalis* is dynamic in summer months, particularly amid the blustery season and less dynamic from November to February. Pinnacle populaces are frequently announced in June-August. Advancement of the distinctive phases of the pest takes longer amid the winter months. *L. orbonalis* populaces are accounted for to increment with normal temperature, relative humidity and precipitation.

Alam *et al.* (1982), Jat *et al.* (2003) and Singh and Singh (2001) revealed that male moths lived for 1 to 3 days and female moths lived for 2 to 5.8 days. The moth was white in colour with blackish brown head and thorax. The whitish wings had pinkish brown markings which are bigger on the forewings. The males were smaller in size, lesser in wing- expanse and narrow or slender abdomen which tapered posteriorly while the females were bigger in size, more in wing expanse and broader abdomen with rounded posterior end (Jat *et al.*, 2003). However, according to Taley *et al.* (1984) and Patial *et al.* (2007), sex ratio was found to be in favour of females 1.0:2.0 and 1.0:1.3, respectively. Raina and Yadav (2017) reported that adults of *L. orbonalis* generally mate during night or early hours in the morning. Pre-mating period varied from 6-9 hours (avg. 7.1 hours). The adults remained in mating position period for 30-49 minutes (avg. 41.2 minutes). Post-mating period varied from 4-6 days (avg. 5.0 days). Yasuda and Kawashaki (1994) also observed that mating normally occurs during the early hours of the day lasted for 43 minutes.

**2.5 Nature of Damage of BSFB**

Shaukat *et al.* (2018) demonstrated that brinjal is commercially very accessible and profitable vegetable to farmers. A wide range of essential biochemicals and minerals belongs to brinjal including vitamins, proteins, calcium and phosphorus. Brinjal Shoot and Fruit Borer (BSFB) *Leucinodes orbonalis* Guenee is the major infectious insect pest causing a high toll to plants. BSFB generally depends on brinjal but sometimes turns towards other solanaceous field crops and may be on wild hosts. The pest is spread to wide areas of eggplant cultivation with South of Sahara, Africa and Asia including China and Philippines. Egg-laying occurs during night and incubation period ranges from 3-8 days depending of environmental conditions. Larval period completes in 12-22 days depending upon environmental situations and passes through five instars. Full grown larvae pupate into the soil or under plant debris and dropped dead shoots. Adult of BSFB is whitish moths which hide during day time and activates from dusk to perform various activities like mating and oviposition. It was investigated that environmental factors have a great impact on the life of *L. orbonalis*. Damage of the pest belongs to all parts of the plants like inflorescence, fruits and shoots. Larvae bore into fruits and shoots and in younger plants, caterpillars drill into midrib of large leaves. At the time of maturity, damage of the insect on fruits causes a serious loss in yield.

*L. orbonalis* attacks for the most part on blossoming, fruiting and vegetative developing stage on fruits, developing parts and inflorescence (CABI, 2007). The higher percent of the larvae was in fruits took after by shoots, blossoms, bloom buds and midrib of leaves (Alpuruto, 1994). Inside one hour in the wake of bring forth, *L. orbonalis* larvae drills into the closest delicate shoot, bloom, or fruit. Not long after in the wake of drilling into shoots or fruits, they attachment or stop up the passageway opening (nourishing passage) with excreta (Alam *et al.*, 2006). In young plants, caterpillars are accounted for to exhaust inside petioles and midribs of extensive leaves (Butani and Jotwani, 1984; Alpureto, 1994; AVRDC, 1998) along these lines shrivelling, drop off and shrink of the young shoots prompting delay on shoot development, decrease on yield and yield parameter. Larval bolstering inside the fruit brings about pulverization of fruit tissue. In serious cases, spoiling was normal (Neupane, 2001). Larval nourishing in bloom was uncommon, if happen, inability to shape fruit from harmed blossoms (Alam *et al.*, 2006). Damage to the fruits, especially in harvest time, is exceptionally extreme and the entire yield can be annihilated (Atwal, 1976). *L. orbonalis* is dynamic during the time at places having moderate atmosphere yet its movement is antagonistically influenced by serious chilling (Naqvi *et al.*, 2009). They found that BSFB pervasion on brinjal started in August and achieved its crest in October and afterward began declining.

Ghosh and Senapati (2009) found that this pest causes the most destruction and is most dynamic amid the late spring months, i.e., from May to August. It turns out to be less dynamic amid the winter months, especially in December and January. Varma *et al.* (2009) considered that the occurrence and plenitude of BSFB in Allahabad, India and watched the most elevated rate on brinjal in December.

Patel *et al.* (1988) discovered shoot and fruit damage in brinjal by BSFB was higher in May transplanted (spring) crops than that in July and September transplanted (fall) crops. The misfortunes caused by insect change from season to season since direct temperature and high moistness support the populace develop of brinjal shoot and fruit borer (Shukla and Khatri, 2010; Bhushan *et al.*, 2011). At vegetative stage, the recently brought forth larvae bore in to petioles and midrib of huge leaves and young delicate shoots they feast upon the inward tissue causing the shoot hung down and wilted at the regenerative stage the larvae like to drill into blossom buds and furthermore go into the plagued fruits through the calyx. Watching the drilling openings, the pervaded fruits can be distinguished without much of a stretch. Furthermore, the dull shaded excreta can be seen without much of a stretch to the opening of pervaded fruits. Optional pervasions by specific microorganisms may create additional decay of the fruits (Islam and Kairm, 1991) and make them at last unfit for human utilization. Larval phase of this pest makes genuine damage to shoots and fruits of eggplant. Larvae drill into the young shoots and feast upon interior tissues bringing about shrinking of the shoot, which diminishes plant development in number and size of fruits (Atwal, 1976). They additionally drill into the plants on inward tissues making crisscross passages. The nourishing passages are frequently stopped up with frass, which makes even somewhat injured fruits unfit for promoting (Alam *et al.*, 2003).

**2.6 Seasonal abundance of BSFB**

Singh *et al.* (2000) observed from an experiment that pest populations at 5-day intervals to assess the population dynamics and economic status of the brinjal shoot and fruit borer (*L. orbonalis*). While the populations of jassids (Cicadellidae), aphids (Aphidoidea) and *Epilachna* sp. were small, *L. orbonalis* was the most serious pest on shoots during September-October. Borer infestation was 73.33% on the top shoots at the beginning of September and infestation peaked (86.66%) by the third week of September, with an intensity of 2.90 borers per plant. Upon initiation of flowering, borer infestation on the shoots declined and reached zero by the end of October. At this stage, borer infestation shifted to the flowers and fruits: percentage fruit infestation reaching 66.66% in the second week of October. Fruit infestation decreased (with a small peak in the third week of November), until 0% infestation was recorded at the start of December. Temperature was positively correlated with pest multiplication (PM), whilst relative humidity was negatively correlated with PM. The extent of apparent losses caused by the borer on fruits was 21.3%. The extent of total losses was 48.3%, of which avoidable losses were 45.9% and unavoidable losses were 2.4%. The calculated economic injury levels of *L. orbonalis* on fruits and on shoots were 0.67% and 0.91%, respectively.

Singh *et al.* (2007) recorded that the pest infestation on shoots started in 1st week of December, increased to the maximum mean shoot damage of 37.03 and 35.25%

during 2003-04 and 2004-05, respectively in 1st week of April and recorded shoot infestation after 2nd week of April. The pest migrated to the fruits during initiation of fruiting stage in the last week of January, reached to a peak of 38.90 (2003-04) and 40.95 (2004-05) percent fruit damage during 2nd week of May. Temperature was positively correlated with its infestation on snoots and on fruits, whereas relative humidity (RH) responded negatively. Further, 10th January planted plots recorded the lowest pest incidence as compared to the plots with other planting dates with maximum fruit yield of 10.35 ton per hectare, but showed non-significant difference between planting dates.

Shukla and Khatri (2010) observed the infestation and intensity of *Leucinodes orbonalis* Guenee on young plants to counting infected and healthy shoots on randomly selected ten plants. The results of two consecutive years revealed that the adults population of brinjal shoot and fruit borer *L. orbonalis* Guenee fluctuated to a great deal not only from year to year but also indifferent months. Adult increased considerably in the month of October and November and decreased insubsequent weeks of December. The maximum temperature and abundance of moth showed a positive correlation ($r = 0.319$) during both the years. The correlation coefficient of minimum temperature and moth trapping also came out was positive ($r = 0.3893$) indicating the minimum temperature plays an important role in building up of moth population.

Atwal and Verma (1972) reported the abundance of *L. orbonalis* Guenee during monsoon period. Many workers also observed maximum population increase of moth between 22 to 35ºC. Mehto *et al.,* (1980) also observed this pest round the year on brinjal crop. Patel *et al.*, (1988) and Dhamdhere *et al.*, (1995) found moderate temperature and high humidity favoured the population build up of *Leucinodes orbonalis* Guen. during the summer.

Pawar *et al.* (1986) found the incidence of this pest during kharif crop and summer seasons. The peak population of this borer was observed in second week of February and first week of summer while Shukla (1989) observed peak population of this borer in first week of July and third week of August. The population was found correlated with average temperature, mean relative humidity and total rainfall. Gupta *et al.* (1987) also found that abiotic factors are responsible for population build up. Prasad and Logiswaran (1997) revealed a significant positive correlation with maximum temperature and relative humidity and negative co-relation with minimum temperature.

According to Suresh and Dharmendra (2013), seasonal incidence of shoot and fruit borer, *L. orbonalis* Guen. (on shoot) was more prevalent during vegetative phase of the crop up to the 3$^{rd}$ week of September. On initiation of fruiting stage there was a continuous decline in the infestation on shoots and it disappeared during fruiting stage of the crop in end of October, as the borer infestation shifted to the fruits reaching in the 2$^{nd}$ week of October. It gradually declined with the advent of winter season and completely wiped out by the end of November. The role of temperature, rainfall, relative humidity (Morning) in increasing infestation and intensity on shoot and fruits was very conductive but RH (%) (Evening) responded negatively. The economic injury level of shoot and fruit borer on brinjal shoots was recorded as 0.96 and 0.90 percent during 1$^{st}$ and 2$^{nd}$ year respectively and on brinjal fruits as 0.81 and 0.72 percent during 1$^{st}$ and 2$^{nd}$ year, respectively.

Raina and Yadav (2017) from Hisar conducted experiments from June to October during 2014, on brinjal (var. BR-112). They found that the infestation of *L. orbonalis* started appearing in shoots during June month, whereas, fruit infestation started appearing in July month. The peak incidence of shoot and fruit borer was observed in third week of September. Highest shoot damage (48.75%), fruit damage (40.00%) on number basis and maximum larval population (12 larvae/20 plants) was recorded in the third week of September, When temperature (max.) was 35.3°C and min. 25.0°C, relative humidity morning 87% and evening 45%.

Patnaik (2000) stated that about the seasonal abundance of aubergine shoot and fruit borer (*L. orbonalis*) which was studied across 12 seasons from 1987 to 1997 in Orissa, India. In July-planted aubergines, the peak infestation levels (in the range 59.2-75.5%) were mostly recorded at 64-88.3 days after planting, during September and October. Relative humidity was the only weather parameter to have a direct effect on pest seasonal abundance. Peak infestation of flower buds occurred during March (68.0%) and August (29.2%).

## 2.7 Management of BSFB

### 2.7.1 Bio-rational management

Tripura *et al.* (2017) conducted an investigation to evaluate some bio-rational pesticides against brinjal shoot and fruit borer (BSFB) under field condition during kharif season of 2015 and 2016 at ICAR Research Complex. The treatments *viz.*, chlorantraniliprole 18.5 SC (0.4 ml/L), spinosad 45 SC (0.5 ml/L), chlorfenapyr 10 SC (2 ml/L), success 2.5 EC (0.5ml/L), *Bacillus thuringiensis* (*Bt*) (2 g/L), azadirachtin 0.03 EC (5ml/L), *Metarhizium anisoplae* (2.5 g/L), *Beauveria bassiana* (2.5g/L), chlorpyriphos 20 EC (2.5 ml/L) were applied thrice at fifteen days interval starting from initiation of BSFB infestation. Mean shoot infestation was minimum in chlorantraniliprole treated plots (6.32%) followed by spinosad, chlorfenapyr, indoxacarb. Among bio-pesticides, *Beauveria* and *Bt* were found effective treatments in reducing shoot infestation. Chlorantraniliprole recorded lowest fruit infestation (8.25%) and highest marketable fruit yield (250.30 q/ha) followed by spinosad and chlorfenapyr.

Islam *et al.* (2016) revealed that the efficacy of three bacterial fermented biopestcides *viz.*, spinosad, emamectin bennzoate and abamectin and one insect growth regulator, buprofezin were evaluated against the infestation of brinjal shoot and fruit borer (BSFB), *Leucinodes orbonalis* (Guen) during January to July 2015. Biopesticides were applied individually or in some selected combinations viz., buprofezin + emamectin benzoate, buprofezin + abamectin, buprofezin + spinosad. It was found that all the treatments significantly reduced percent shoot (15.66-63.99% reduction) and fruit infestation (17.27-70.75% reduction) and increased marketable fruit yield over control (12.87-84.33%increase). The best result was found in case of combined treatment buprofezin + emamectin benzoate treated plots (70.75% shoot and 63.99% fruit protection; highest marketable fruit yield of 9.94 t/ha) whereas the least protection was obtained from buprofezin (1 ml/L) treated plots (17.27% shoot and 15.66% fruit protection; lowest marketable fruit yield of 6.05 t/ha).

Budhvat and Magar (2014) demonstrated that a field experiment was conducted in the insectary premises, during kharif season of 2010-11 to the bio-rational management of brinjal shoot and fruit borer, *L. orbonalis* Guen. During the investigation, it was revealed that lowest infestation (shoot and fruit infestation) and highest yield over control was observed in the treatment spraying of spinosad 45 SC @ 0.01% (256.71 q/ha) followed by the treatment spraying of cypermethrin 25EC @ 0.0075%, clipping of shoot +NSE 5%, spraying of Sevin 50 WP @ 1g/L, release of *T. chilonis* @ 7.5 cc eggs/ha; release of *T. chilonis* @ 6 cc eggs/ha; release of *T. chilonis* @ 5 cc eggs/ha; release of *C. carnea*; spraying of *M. anisopliae* @ 1 L/ha; clipping of shoot from initiation of infestation. The ICBR was highest in the treatment cypermethrin 25 EC @ 0.0075% (i.e. 43.02). Among microbial, bio agent, botanical and insecticide, the treatment *T. chilonis* @ 7.5 cc eggs/ha shown promise in managing brinjal shoot and fruit borer and registered 25.46 ICBR next to cypermethrin treatment.

Noor *et al.* (2017) found out the most effective bio-rational management options against brinjal shoot and fruit borer (BSFB) with 6 treatments namely Fytomax 3 EC (Azadirachtin) @ 1ml/L, Fytoclean (Potassium salt of fatty acids) @ 5 ml/L, Neem seed kernel extract (Azadirachtin) @ 50g/L, Tracer 45 SC (Spinosad) @ 0.4 ml/L, Mechanical control (hand picking) with clean cultivation and untreated control. Results revealed that the lowest shoot infestation at both pre-fruiting (4.34%) and at fruiting stage (3.55%) was in Tracer 45 SC treated plot and the highest was in untreated control plot (21.43% at pre-fruiting stage and 21.42% at fruiting stage). The lowest fruit infestation by BSFB was obtained with Tracer 45 SC (5.90% n/n and 2.45% w/w) followed by Neem seed kernel extract (9.28% n/n and 9.92% w/w) and the highest infestation was observed under untreated control plot (36.57% n/n and 32.42% w/w). Percent reduction of infested fruit by number (83.86%) and weight (92.44%) over untreated control was higher in Tracer 45 SC treated plot resulting significantly higher marketable yield. Therefore, the significant highest marketable yield (21.97 t/ha) was harvested in the plot treated with Tracer 45 SC followed by 17.98 t/ha$^{-}$ with Neem seed kernel extract and 16.46 t/ha from Fytoclean treated plot. The highest benefit cost ratio of 5.62 was obtained from Tracer 45 SC followed by 4.97 in Neem seed kernel extract and 3.45 with Mechanical control plot.

Mainali *et al.* (2013) carried out a field experiment to evaluate the efficacy of different management treatments as, i) *Bacillus thuringiensis* var. *kurstaki* (Berliner) (Btk) @ 2 g/L; ii) Nimbecidine (Azadirachtin 0.003 EC) @ 5 ml/L; iii) Chinaberry fruit extract (CFE) @ 1:5 ratio; iv) Anosom (fraction of *Annona squamosa* Linnaeus) @ 2 ml/lt; v) Spinosad 45 SC @ 0.5ml/L; vi) Cypermethrin 10 EC @ 2 ml/L; and vii) Fruit infestation percent on number and weight basis was the lowest in Abamectin treated plots (17.42 and 16.13) followed by Cypermethrin (29.13 and 27.80), Btk (31.26 and 29.17), Nimbecidine (35.66 and 33.79), Anosom (42.22 and 39.66), CFE (62.94 and 60.02) and untreated check (75.84 and 73.58), respectively. The highest marketable fruit yield (28.75 mt/ha) was obtained in Abamectin treated plots followed by Cypermethrin (23.91 mt/ha), Btk (22.10 mt/ha), Nimbecidine (21.19 mt/ha), Anosom (18.59 mt/ha), CFE (12.23 mt/ha) and untreated check (7.67 mt/ha), respectively. The marketable yield increment over untreated control was the highest in Spinosad 45 SC (275%) followed by Cypermetrhirn (212%), Btk (188%), Nimbecidine (176%), Anosom (142%), CFE (59%), respectively. Similarly, the highest yield loss reduced by the use of Abamectin (74%), Btk (60%), Cypermethrin (58%), Nimbecidine (50%), Anosom (43%), CFE (16%) respectively. From this study, it was concluded that Spinosad 45 SC and Btk is the most viable bio-rational options for *L. orbonalis* management.

Choudhary *et al.* (2018) conducted an experiment at the Horticulture Farm, Rajasthan during Kharif 2014-15 and 2015-16 for bio-efficacy of bio-rational insecticides against larval population of *Leucinodes orbonalis* (Guen.) in brinjal. The data revealed that maximum reduction in larval population of *L. orbonalis* was recorded in the treatment schedule $T_2$ (three sprays of Chlorantraniliprole 18.5 SC @ 150 ml/ha) with cumulative mean reduction of 70.24, 75.24, 64.74 and 70.59, 76.95 and 64.90 percent; while, minimum larval population reduction of 34.86, 39.44, 32.18 and 34.88, 39.21 and 30.41 percent was recorded in treatment schedule $T_3$ (three sprays of NSKE 5% /ha) at 3, 7, and 10 days after sprays, respectively during 2014-15 and 2015-16.

### 2.7.2 Biological control

#### 2.7.2.1 Sex Pheromone

Sex pheromones are considered as important IPM component and they are widely used to monitor and mass-trap the male insects of several crops. The use of sex pheromones in brinjal attracted several adult male moths and reduced the adult population of *L. orbonalis* (Mathur *et al.*, 2012). The major component of BSFB sex pheromone was identified and synthesized in laboratory was (E)-11-hexadecenyl acetate (E11-16: Ac) in China (Zhu *et al.*, 1987). The compound was used at the rate of 300-500 and was tested for its efficacy in Sri Lanka. However, the synthetic product was inferior and less effective to live virgin female moths (Gunawardena *et al.*, 1989). But, the high number of male moths were trapped by the combination of (E)-11-hexadecenyl acetate and (E)-11hexadecen-1-ol and significantly reduced the pest damage in India and Bangladesh (AVRDC, 1996; Srinivasan, 2009; Srinivasan, 2008; Alam *et al.*, 2011). The use of pheromone traps was found effective in reducing shoot damage and fruit infestation with 46.15 percent protection and 25.6 percent protection over control respectively (Mathur *et al.*, 2012).

In field conditions, delta traps and funnel traps are also useful for luring adult moths by using sex pheromones and this can also help in reducing the infestation of adult insect. However, the trap design, trap location and the height of the location of the trap greatly influenced the number of insects attracted to the traps. Dutta *et al*. (2011), from his experiment in field condition found that the use of pheromone trap starting from 15 days after transplanting till final harvest gave substantial protection in shoot damage (58.39%), fruit damage (38.17%) and 49.71% increase in yield over control. Thus, the use of sex pheromones is one of the most important methods in controlling *L. orbonalis* (Mathur *et al.*, 2012).

Use of sex pheromone for *L. orbonalis* (a blend of (E)-11-hexadecenyl acetate and (E)-11-hexadecen-1-ol) showed promising effect (Zhu *et al*., 1987; Attygale *et al*., 1988; Cork *et al*., 2001). Sex pheromone chemicals are increasingly used to control insect pests of vegetables and fruits. Zhu *et al*. (1987) working in China identified (E)-11-hexadecenyl acetate (E11-16:Ac) as the major component of the female sex pheromone of *L. orbonalis* and suggested that it was attracting male moths in the field. Subsequently, Attygale *et al*. (1988) confirmed the presence of E11-16:Ac in virgin females using insects from Sri Lanka.

AVRDC obtained pure chemicals and tested mixtures of varying proportions of E11-16:Ac and E11-16:OH in selected locations in Asia. Results of field studies in Bangladesh and later in India indicated that high concentrations of E11-16:Ac alone or low concentrations of mixtures of E11-16:Ac and E11-16:OH (10:0.5 or 10:1) attract large number of male moths to pheromone-baited traps (Kumar and Babu, 1997; Srinivasan and Sundara Babu, 2000). These results formed the basis for inclusion of sex pheromone as one of the components of IPM of *L. orbonalis* (Alam *et al*., 2003). Despite the high initial fruit damage in the mature crop, within two weeks of installation of pheromones, the fruit damage reduced to 35% as compared to 55% in insecticide treated plots (Cork *et al*., 2003).

**2.7.2.2 Pheromone trap**

Alam *et al.* (2003) cited that the marketable fruit yield was greater in pheromone-treated plots than in check plots. They also found that the number of insects trapped at the 0.5 m height was significantly greater than at the 1.5 m height.

Cork *et al.* (2003) ponted that delta and wing traps baited with synthetic female sex pheromone of *L. orbonalis* were found to catch and retain ten times more moths than either Spodoptera or uni-trap designs. Locally produced water and funnel traps were also found as effective as delta traps, although ‘windows’ cut in the side panels of delta traps, significantly increased the trap catch from 0.4 to 2.3 moths per trap per night.Wing traps placed at crop height caught significantly more moths than traps placed 0.5 m above or below the canopy. However, Chatterjee (2009) stated that the setting of pheromone trap @ 75 numbers per hectare gave quite substantial protection from *L. orbonalis* in shoot damage (58.35%), fruit damage (33.73%) and yield (28.67%) in brinjal crop.

Rani (2013) conducted field studies on brinjal shoot and fruit borer, *L. orbonalis* with sex pheromone trap at nine villages in and around Bangalore rural district during 2012-13. The four different trap heights were evaluated for optimum BSFB moth catches. The results revealed that traps at the greatest height of 0.6 m above crop canopy recorded with maximum number of moth catches (499 moths). Similarly five different trap densities (i.e., 8, 16, 24, 32 & 40 traps/acre) were also evaluated and they found that 16 traps/acre recorded with maximum moth catches (1097 moths) and less fruit damage (6.48%).

Alam *et al*. (2003) reported from an experiment that Gujarat Agricultural University (GAU) tested the standard delta trap and two plastic funnel traps commercialized by two local companies in India. Indian Institute of Vegetable Research (IIVR) tested three traps: a funnel trap, delta trap, and a locally made water-trough trap similar to the one used by Bangladesh Agricultural Research Institute (BARI). BARI tested delta, open delta, funnel, uni, *Spodoptera*, and locally designed water- trough traps. Lures loaded with 3 mg of sex pheromone were used. Traps were placed in BSFB-infested brinjal fields just above the crop canopy. The number of male BSFB adults trapped were recorded at regular intervals over varying lengths of time reaching upto 5 weeks.

Cork *et al*. (2003) revealed that at GAU, the ‘delta’ trap consistently caught more BSFB male adults than the other trap designs, Phero and the Nomate. The latter two were essentially funnel traps of similar design and caught similar numbers of insects. Researchers at the GAU site, preferred funnel traps for further studies as the sticky surface of delta traps were inconvenient and costlier than funnel traps. At IIVR, funnel traps consistently trapped more BSFB adults than delta or water-trough traps. Several sets of tests were conducted at BARI to select an efficient trap that was cost effective and locally available and finally recommended open delta trap to catch greater number of BSFB males (Alam *et al.*, 2003).

### 2.7.3. Bio-Control Agents

#### 2.7.3.1 *Trichogramma* Spp.

Murali *et al.* (2017b) conducted an experiment in which six species of *Trichogramma* were used for selection of most suitable species against shoot and fruit borer, *L. orbonalis*, the percent parasitism ranged between 3.60 to 93.20 per cent and the highest per cent parasitism was observed in *T. evanescens* (93.20 %), which was on par with *T. chilonis* 92.00 percent. In a dosages experiment, the highest percent parasitism of 74.1 percent was recorded in the dosage having 15 adults/sq. m (150,000 adults/ha) and lowest parasitism of 44.2 percent was recorded in dosages of 5 adults/sq. m (50,000 adults/ha). Among the two species highest parasitism was recorded in the *T. chilonis* (68.0%) compared to *T. evanescens* (55.9%) and 100,000 was found to be optimum dosages.

The selection of most promising species or strains of *Trichogramma* has been advocated as first step in achieving successful control program (Hassan, 1989). In an earlier studies in the Philippines, Alpuerto (1984) reported that The results were showing more parasitization when compared with the study reported by himself from Philippines that parasitism by *T. chilonis* ranged from 34.6 to 51.3 percent on *L. orbonalis* eggs and Nafus and Schreiner (1986) were of the opinion that *T. chilonis* is the most important natural enemy attacking the pyralid pests. *Trichogramma* viability is a feature closely related to the parasitoid host resemblance (Bezerra and Parra, 2004). In *Trichogramma* production, quality control considers practicality as acceptable when the rate of borne adults exceeds 85 percent (Navarro, 1998).

Mondal *et al.* (2008) implemented an experiment at IPM laboratory, Entomology Division, Bangladesh Agricultural Research Institute (BARI), Gazipur, to evaluate the effect of *Sitotroga cerealella* stored eggs of different duration on the parasitism of *Trichogramma chilonis, T. japonicum* and *T. evanescens.* With the increase of storage period of the host eggs, the parasitism affinity reduced. A negative correlation was observed with the storage period of host eggs and percent egg parasitism and adult emergence of parasitoids from the parasitized eggs. This suggests that fresh eggs are preferred to older egges for parasitism.

Begum *et al.* (2013) stated that a study was undertaken to develop an effective mathod for mass rearing of *Trichogramma evanescens* and *T. chilonis* under laboratory condition and to assess the effect of parasitoid age and the age of host eggs to ensure maximum parasitization. The parasitoids were reared on eggs of *Sitotroga cerealella* and *Corcyra cephalonica* under 27±2°C, 65±5% RH and natural photoperiod. The results showed that adult emergence exceeded 90% on both the hosts and egg parasitizations ranged from 81.13% to 94.47%. The adult longevity and emergence rates ranged from 4.1 to 4.5 days and 90.86% to 91.13%, respectively. The overall results manifested no significant difference. Higher egg parasitism was caused by *T. chilonis* reared on *C. cephalonica* eggs (94.47%) compared to *T. evanescens* (93.87%). Effect of different ages (8, 16 and 24 h) of eggs on parasitism did not differ significantly. In both the studies, the developmental period of *T. evanescens* inside the host eggs remained almost similar, while the 24 h old *T. evanescens* parasitized eggs (96.75%) was followed by 48 h old parasitoids (87.25%). Use of younger parasitoids and host eggs were found better for parasitization. The suitable age of host eggs was found to be 8-24 h to achieve maximum parasitization for large scale production of *T. evanescens*. It was also found that under laboratory conditions, both *T. evanescens* and *T. chilonis* were effective for rearing.

*Trichogramma* spp., the most widely studied and used parasitoid in the world were field released for control of lepidopterous pests (Greenberg *et al*., 1996; Smith, 1996). *Trichogramma* is a genus of minute polyphagous wasps that are endoparasitoids of insect eggs (Flanders and Quidnau, 1960). *Trichogramma* is one of around 80 genera from the family Trichogrammatidae, with over 200 species worldwide (Consoli *et al.*, 2010; Sumer *et al.*, 2009).

Knutson (2005) reported that although several groups of egg parasitoids are commonly employed for biological control throughout the world, *Trichogramma* spp. have been the most extensively studied. More than a thousand papers have been published on *Trichogramma* species, and they are the most used biological control agents in the world. The first description of a *Trichogramma* species was in North America in 1871, by Charles V. Riley. He described the tiny wasps that emerged from eggs of the viceroy butterfly as *T. minutum*. In taxonomy, original specimens are very important, as they are the basis of reference for subsequent descriptions of species. The original specimens, however, were lost. Riley also described a second species in 1879 as *T. pretiosum*, but these specimens were also lost. To correct these errors, entomologists returned to the areas where Riley originally found the species and obtained neotype specimens of *T. minutum and T. pretiosum*. These specimens are now preserved properly in the United States National Museum. To locate host eggs, adult females use chemical and visual signals, such as egg shape and colour. After she finds a suitable egg, an experienced female attempts to determine if the egg has previously been parasitized, using her ovipositor and antennal drumming (tapping on the egg surface). Females also use antennal drumming to determine the size and quality of the target egg, which determines the number of eggs the female will insert (Klomp *et al.*, 1979). A single female can parasitize up to 10 host eggs a day.

*Trichogramma* wasps are small and very uniform in structure, which causes difficulty in identifying the separate species (Thomson *et al.*, 2003). According to Polaszek *et al.* (2012) as females are all relatively similar, taxonomists rely upon examination of males to tell the different species apart, using features of their antennae and genitalia. Currently, the number of *Trichogramma* species is over 200, but as of 1960, only some 40 species of *Trichogramma* had been described.

#### 2.7.3.2 Braconid wasp

Tewari and Sandana (1990) evaluated that a larval ectoparasite, *Bracon* sp. on *L. orbonalis* on eggplant in Karnataka, India and stated the possibility of its use in the biological control of the pest. It pupated in a silken cocoon inside the tunnel made by the host and parasitization ranged from 9.2 to 28.1%. It was regarded as a promising parasitoid.

Naresh *et al.* (1986) pointed that the *L. orbonalis* larval population peaked in May and the pest was active throughout the year where *Trathala* sp. caused 12.90-18.18% parasitism of larvae. The parasitoid was active throughout the summer and winter seasons and preferred mature host larvae.

Mohanty *et al.* (2000) carried out a field experiment during 1997-99 to study the management of *L. orbonalis* on aubergine cv. Black Beauty-102 using *Bracon brevicornis* as a biological control agent. Shoot (0.2-10.2%) and fruit (0.1-5.1%) damage was reduced in the parasitoid released field compared to the control during 1997-98. Similar results were obtained during 1998-99. The percent reduction in shoot and fruit damage over control gradually increased with the number of releases along with the age of the plants.

Murali *et al.* (2017a) investigated to document parasitoids which are attacking brinjal shoot and fruit borer, *L. orbonalis*. To study this infested fruits collected from sprayed and unsprayed areas kept under caged condition to observe emergence of parasitoids. A total of 16 species of parasitoids were recorded on L. orbonalis consisting of Ichneumonidae (5 species), Pteromalidae (3 species) viz., Braconidae (2 species) viz., *Phanerotoma* sp. and Indeterminate Braconidae, Trichogrammatidae (6 species), *Trathala flaororbitalis* was recorded as most dominant parasitoid, the number of females emerged from Attur Farm, Chikkaballapur and Doddaballapur was 4.48, 2.80 and 2.77, respectively, whereas for another important parasitoid, indeterminate Braconidae, population recorded was 3.18, 2.34 and 1.97, respectively. The larval parasitoid population was 35.9 and 61.4 percent higher in unsprayed area (Attur Farm) compared to two sprayed areas. Among egg parasitoid, *T. chilonis* was most dominant species. In unsprayed area, the population was 107-120 percent higher when compared to sprayed areas.

Sixteen parasitoids, three predators and entomopathogens were reported as natural enemies of *L. orbonalis* all over the world (Khorsheduzzaman *et al.,* 1998), with only least significant role in keeping *L. orbonalis* damage under reasonable control (Srivastava and Butani, 1998), especially in South Asia. Among Ichneumonoidea, *Trathala flavo-orbitalis* (Ichneumonidae), *Phanerotoma* sp. (Braconidae), *Chelonus* sp. (Braconidae), *Vaepellinae* sp. (Braconidae) and *Bracon hebetor* (Braconidae) were recorded in brinjal growing tracts.

# CHAPTER III

# MATERIALS AND METHODS

The brinjal shoot and fruit borer, *Leucinodes orbonalis* is the most serious and destructive pest throughout Bangladesh. The excessive usage of pesticides for managing this pest threatens the health of farmers and consumers, and makes the brinjal fruits more costly to consumers. Hence, a bio-rational based management practices including bio-control agents (parasitoids) study was conducted on *L. orbonalis* at the experimental field of Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh during October, 2018 to March, 2019. The details of methodology of experiments conducted are described hereunder.

## 3.1 Experimental site

The experiment was performed in the Research field of Sher-e-Bangla Agricultural University, Dhaka, which is located at 23°41′N latitude and 90°22′E longitude with the elevation of 8.6 meter above sea level. The experimental site belongs to the Agro-ecological zone of "The Modhupur Tract", AEZ-28 **(**Anon., 1988**)** and it is shown in the AEZ Map of Bangladesh in Appendix I.

## 3.2 Soil

The soil of research field was general soil type. It was a medium high land with Shallow red brown terrace soils under Tejgaon series. The soil pH of the experimental field was 5.6 and had low amount of organic matter (1.19%). The physicochemical properties of experimental soil analyzed in the Soil Testing Laboratory, SRDI, Dhaka is showed in Appendix II.

## 3.3 Climate

The climatic state of Sher-e-Bangla Agricultural University farm, Dhaka is under subtropical, characterized by high temperature, high relative humidity and heavy rainfall with occasional gusty winds in Kharif season (April-September) and scanty rainfall associated with moderately low temperature during the Rabi season (October-March). The weather data of the experimental site during the conduction of the experiments recorded by the meteorology center, Dhaka for the study period is presented in Appendix IV.

### 3.4 Planting material

The Hybrid variety (Begun-706) of brinjal was selected for the experiment during Rabi season 2018-2019. The seed of this variety was collected from Manik Seed Company, Siddique Seed Bazar, Gulistan, Dhaka.

### 3.5 Land preparation

The land was first opened with a power tiller, and left exposed to the sun for a week. Then cross ploughing was done two times with a country plough followed by laddering to make the land suitable for growth of brinjal seedlings. All weeds, stubbles and residues were removed from the field. Finally, a good tilth was achieved. Experimental land was divided into unit plots following the design of experiment, after land preparation. The plots were raised by 10 cm from the soil surface keeping the drain around the plots.

### 3.6 Manures and fertilizers application

Brinjal being a long duration crop requires a good amount of manures and fertilizers. The fertilizers nitrogen, phosphorous, and potassium were applied in the form of Urea, Triple Super Phosphate (TSP) and Muriate of Potash (MP) respectively. Manures and fertilizers that were applied to the brinjal field presented in the following:

Dose of application of fertilizers in Brinjal Field (Chowdhury and Hassan, 2013)

| Fertilizers and Manures | Dose $ha^{-1}$ |
|---|---|
| Cowdung | 10 ton |
| Urea | 375 kg |
| TSP | 150 kg |
| MP | 250 kg |

The entire amount of cowdung, TSP and half of MP were applied during land preparation. The remaining half of MP and entire amount of urea were applied in three equal installments at 20, 40 and 60 days after transplanting.

### 3.7 Treatments of the experiment

The treatment combinations of this experiment will be as follows:

**$T_1$**= Cultural method (clean cultivation to keep the plot free from weeds and debris to discourage pupation of insect) + mechanical control method (removal of infested roots, shoots and fruits) at the 7 days interval

**$T_2$**= Braconid wasps at the rate of 20-25/plot at weekly interval + field sanitation

**$T_3$**= Sanitation at the 7 days interval + using Funnel Pheromone trap

**$T_4$**= Field sanitation + Spraying Sevin 50 WP @ 1.0g/L at 7 days interval

**$T_5$**= Spraying Success 2.5 EC @ 0.5 ml/L of water at 7 days interval + using Pheromone trap

**$T_6$**= Spraying Spinosad 45% SC @ 0.01% at 20 days interval + using Funnel Pheromone trap

**$T_7$**= Sanitation + *Trichogramma evanescens* at the rate of 1 card/plot at weekly interval (1000 eggs per card)

**$T_8$**= Untreated control

### 3.8 Experimental layout and design

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications ($R_1$, $R_2$, $R_3$) in the central farm of SAU. The area was divided into three equal blocks. Each block was divided into 8 plots, where 8 treatment combinations were allocated at random. There were 24 unit plots altogether in the experiment. The size of the each unit plot was 3.0 m × 2.0 m. The distance maintained between two blocks and two plots both were 0.5 m (Appendix III) (Plate 1).

Plate 1: Experimental field during the study period.

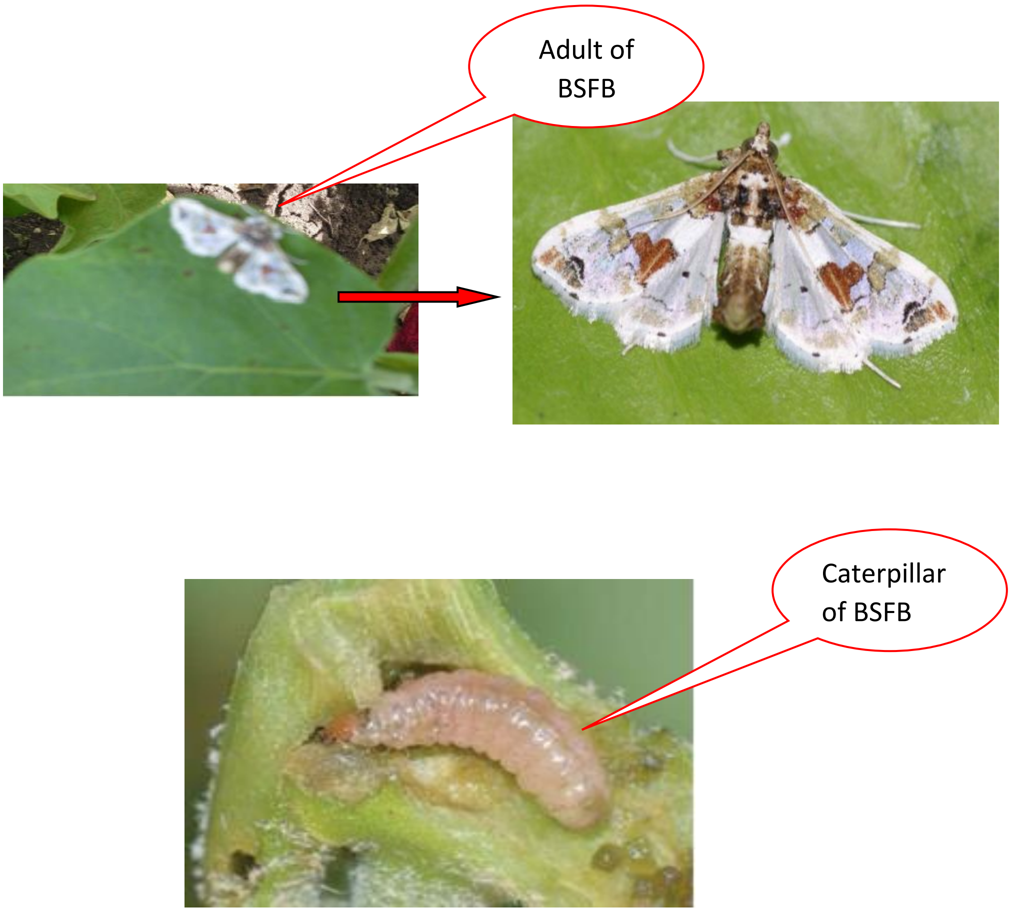



Plate 2: Adult and caterpillar of Brinjal Shoot and Fruit borer, *L. orbonalis*.

### 3.9 Seeds sowing, seedling raising and transplanting

Collecting seeds of Begun-706 (Hybrid variety) of Brinjal were soaked for 12 hours in water for rapid and uniform germination. Then, the seeds were sown in the seedbed at 20th October, 2018. Sevin 50 WP and Furadan 5 G were used in the seedbed to protect the seeds and seedlings from ants and cutworm. The beds were lightly irrigated regularly in the morning and evening for ensuring proper growth and development of the seedlings. After 30 days (20th October, 2018) old healthy seedlings (3/4 leaf stage) were transplanted in the experimental plots. 12 seedlings were planted in each plot.

### 3.10 Collection of trap and trap materials

The commercial formulation of Q-lure (Sex pheromone) with general pheromone trap was collected from Ispahani Agro-Biotec Ltd. Konabari, Gazipur and local made /dwelling made different traps materials were collected from local market.

### 3.11 Preparation of the different traps used as treatments

The sex pheromone, ‘cuelure’, which mimics the scent of female flies, attracts the male flies and traps them in large numbers resulting in mating disruption.

#### 3.11.1 Sex pheromone trap

Pheromone trap was collected from Ispahani Agro- Biotec Ltd. Konabari, Gazipur and set in the experimental field (Plate 3). Sex pheromone trap designed by BARI with Q-lure and soapy water, were used to conduct this experiment. The traps were hung up under bamboo scaffold, 60 cm above the ground. The soap water was replaced by new soap water at an interval of 4 days each.

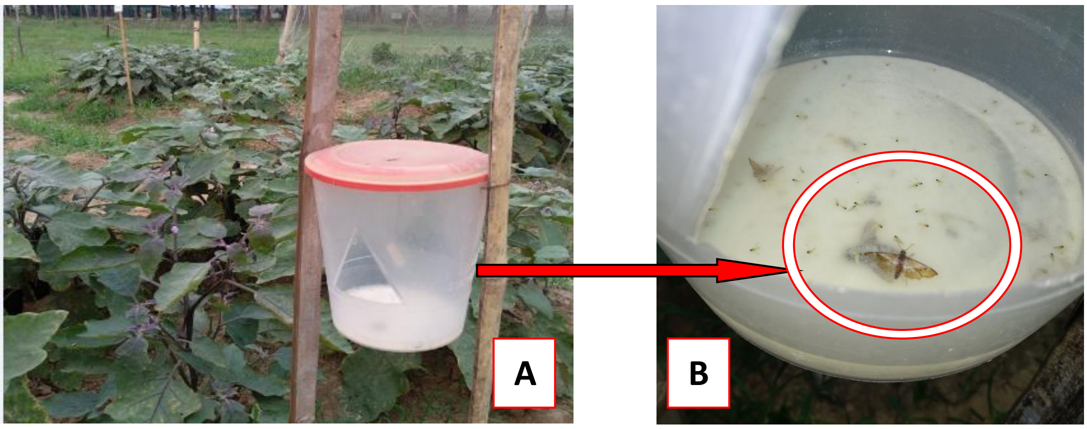



Plate 3: Sex pheromone trap in the brinjal field (A) and Moth of BSFB caught in the trap (B)

### 3.11.2 Funnel pheromone trap

Pheromone trap was made up of a normal plastic bottle with its both sides had two funnels. Cue-lure was hanged inside the plastic bottle. A small portion of this bottle was filled up by soapy water. The soapy water was replaced at an interval of 4 days each (Plate 4).

Plate 4: Funnel pheromone trap in the experimental brinjal field

### 3.12 Collection of Different Bio-Control Agents

Bio-control agents such as. egg parasitoid (*Trichogramma evanescens*) and larval parasitoid (Braconid wasps) were collected from Ispahani Agro- Biotec Ltd. Konabari, Gazipur.

### 3.13 Application of Bio-Control Agents

*Trichogramma evanescens* and Braconid wasps were applied in the selected plot at afternoon. The applied rate of *Trichogramma evanescens* and Braconid wasps were 1 card/plot (1000 eggs per plot) and 20-25/plot at 7 days interval, respectively.

### 3.14 Application of Bio-Rational Based Insecticides

Spinosad 45% SC, Sevin 50 WP and Success 2.5 EC were sprayed in assigned plots with recommended dosages by a Knapsack sprayer. The spraying was always done in the afternoon to avoid bright sunlight and drift caused by strong wind and adverse effect of pollinating bees. The spraying materials were applied uniformly to obtain complete coverage of whole plants of the assigned plots. Caution was taken to avoid any type of drift of the spray mixture to the adjacent plots at the time of the spray application. At each spray application, the spray mixture was freshly prepared.

**3.15 Intercultural operations**

After transplanting of seedlings, a light irrigation was given and replanting was done with healthy ones in place of any damaged seedlings. Supplementary irrigation was applied at an interval of 2-3 days. Weeding and others sanitations practices were done as and whenever necessary for better growth and development of the brinjal. Urea and MP were top dressed in 3 splits as described earlier.

**3.16 Monitoring of infestation**

For the purpose of determining the incidence of adults and the level of infestation during insecticide application, a close monitoring of egg deposition until the eggs were first observed and of shoot infestation up to fruit set, and fruit infestation up to final harvest has been carried out at every alternate days from 6 plants per plot. The infestation data collected have been transformed into percent each time further that the application of insecticide can be made whenever it reaches the pre-set level.

**3.17 Data collection**

The brinjal plants of different treatment were closely examined at regular intervals commencing from germination to harvest. Six plants from each treatment were randomly marked inside the central row of each plot with the help of sample card for collecting data.The following parameters were considered for evaluating the effectiveness of each treatment in controlling the brinjal shoot and fruit borer infestation:

- Number of healthy shoots
- Number of infested shoots
- Shoot infestation in number (%)
- Number of healthy fruits
- Number of infested fruits

- Fruit infestation in number (%)
- Weight (g) of healthy fruits
- Weight (g) of infested fruit
- Fruit infestation in weight (%)
- Weight (g) of Single Fruit
- Length of Single fruit (cm)
- Girth of Single fruit (cm)
- Fruit yield per plot (kg)
- Fruit yield per hectare (ton)

### 3.17.1 Shoot infestation

The total number of shoots and the number of infested shoots were recorded from 6 tagged plants from each plot at 15 days intervals during the period from December, 2018 to March, 2019 and the percent shoot infestation and its reduction over control were calculated for all the treatments In mechanical control, the infested shoots were clipped, removed and destroyed after counting. Shoot infestation was calculated in percent using the following formula:

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

### 3.17.2 Fruit infestation in number and weight

At each harvest, data on the number of healthy and infested fruit separately per plot per treatment were recorded from 6 tagged plants at 7 days intervals. Seven harvests were done throughout fruiting season. Fruits were harvested at 7 days interval. Fruit infestation was calculated using the following formula:

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

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

For obtaining healthy fruit yield and infested fruit yield, the weights of healthy fruits and infested fruits per 6 tagged plants per plot of 7 harvests have been summed up and then transformed into per plot healthy fruit yield and infested fruit yield. The plot yield of healthy and infested fruit thus obtained has been then transformed into healthy fruit yield and infested fruit yield in ton per hectare. Sum of the healthy fruit yield and infested fruit yield is finally expressed as the total yield in ton per hectare.

### 3.18 Harvest and postharvest operations

Harvesting of fruit was done when the fruits attained marketable sized. The optimum marketable sized fruits were collected by hand picking from each plot and yield was converted into t $ha^{-1}$.

### 3.19 Procedure of data collection

#### 3.19.1 Single Fruit weight

Healthy and infested fruits were collected from 6 randomly selected plants and Weight of single fruit was measured by randomly taken 5 fruits in each plot and the mean weight was expressed on per fruit basis in gram (g).

#### 3.19.2 Fruit length

Healthy and infested fruits were collected from 6 randomly selected plants and length of fruit was measured by randomly taken 5 fruits in each plot and the mean length was expressed on per fruit basis in centimeter (cm).

#### 3.19.3 Fruit girth

The circumstances of total fruits of 6 randomly selected plants were measured with a meter scale at base, middle and upper level from randomly chosen 5 fruits. Then, the average were calculated and expressed in centimeter (cm). Data were recorded from the inner rows plant of each plot during harvesting period.

Plate 5: Healthy Binjal plant in the Experimental field during the study period

Plate 6: Infested shoot of brinjal plant by BSFB in the Experimental field

Plate 7: Healthy Brinjal plant with fruit in the Experimental field

### 3.20 Statistical analysis

The data on different parameters as well as yield of brinjal were statistically analyzed to find out the effect of bio-rational based management including bio-control agents (parasitoids) against Brinjal Shoot and Fruit Borer (BSFB). The mean values of all the characters were calculated and analyses of variance were performed by the 'F' (variance ratio) test. The significance of the differences among the mean values of treatment in respect of different parameters was estimated by the Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

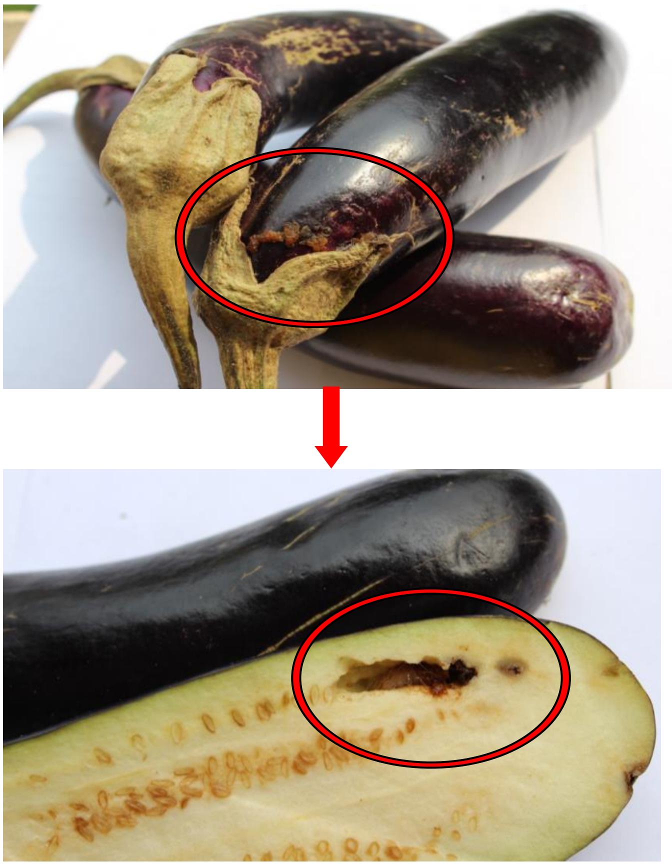


Plate 8: BSFB Infested fruit of brinjal harvesting during the study period

Plate 9: Healthy Brinjal fruit after harvesting during the study period

# CHAPTER IV

# RESULTS AND DISCUSSION

The study was conducted to find out the effect of some bio-rational based management practices in controlling brinjal shoot and fruit borer in brinjal in the central farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh during the period from October, 2018 to March, 2019. The results of comparative effectiveness of treatments consisting of various control measures in reducing the infestation of brinjal shoot and fruit borer (BSFB) was evaluated. Influence of these treatments on yield, extent of damage were presented and discussed under the following Sub-headings:

## 4.1 Effect of different treatments on shoot infestation of brinjal at different days after transplanting (DAT)

### At 55 DAT

Number of healthy and infested shoot, infestation percentage showed statistically significant differences due to different bio-rational management as treatments in controlling brinjal shoot and fruit borer of brinjal (Figure 1) at 55 DAT.

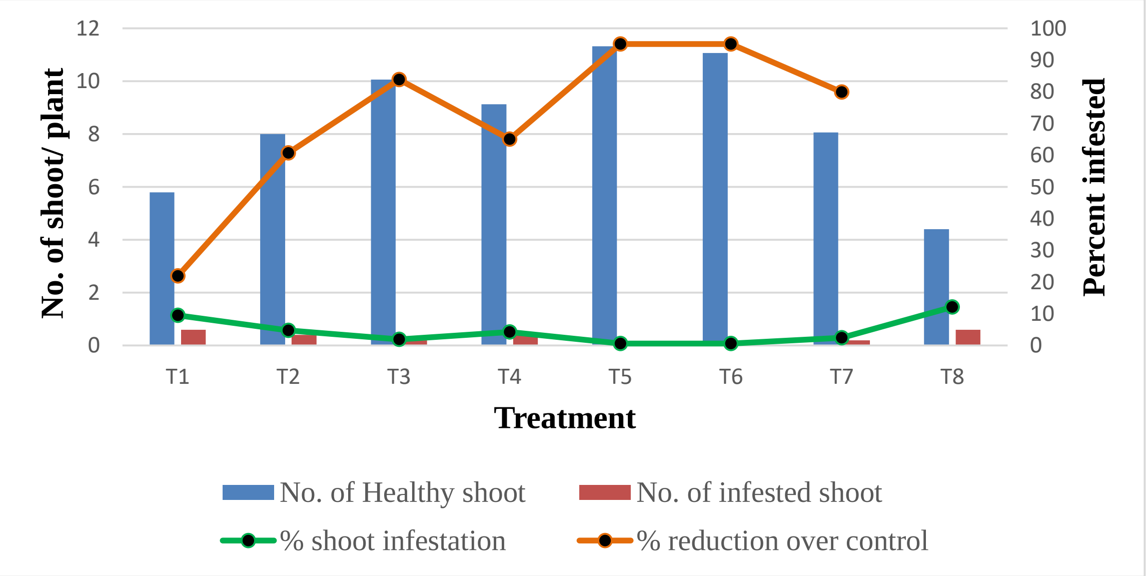
The highest number of healthy shoots plant$^{-1}$ (11.33) was recorded from $T_5$ (spraying success 2.5 EC @0.5 ml/L of water + using pheromone trap) treatment which was statistically different from the rest of the treatment except $T_6$ (Spraying Spinosad 45% SC @ 0.01% + using Funnel Pheromone trap) (11.07) and $T_3$ (Sanitation at the 7 days interval + using Funnel Pheromone trap) treatment (10.07), whereas the lowest number of healthy shoots per plant (4.40) was found from $T_8$ (untreated control) treatment followed (5.80, 8.0, 8.07 and 9.13) by $T_1$ (cultural method + mechanical control method), $T_2$ (Braconid wasps at the rate of 20-25/plot), $T_7$ (Sanitation +Braconid wasps at the rate of 20-25/plot) and $T_4$ (Field sanitation + Spraying Sevin 50 WP @ 1.0g/L of water), respectively (Figure 1).

The lowest number of infested shoots plant$^{-1}$ (0.07) was recorded from $T_5$ treatment $T_6$ treatments, which were statistically different from $T_3$, $T_7$, $T_2$ and $T_4$ treatment. On the other hand, the highest number of infested shoots was obtained from $T_8$ (0.60) treatment which was statistically similar with $T_1$ (0.6) treatment.

Considering the percentage (%) of shoot infestation, the lowest infested shoots per plant in number was recorded from $T_5$ (0.59%) which was statistically similar to $T_6$ (0.60%) followed by $T_3$ (1.96%) and $T_7$ (2.44%). The maximum infested shoots were recorded in $T_8$ (12.14%) which was statistically different from rest of the treatment.

Infestation of shoot reduction over control in number was recorded and the maximum value was found from the treatment $T_5$ (95.14%) followed by $T_6$ (95.06%), $T_3$ (83.86 %) and $T_7$ (79.90%) treatments and the minimum reduction of shoot infestation over control from $T_1$ (21.91%) followed by $T_2$ (60.71%) and $T_4$ (65.07 %) treatment.

This finding showed similarity with Mohanty *et al.* (2000) who showed parasitoids positive efficiency against BSFB and reported that shoot damage (0.2-10.2%) was reduced in the parasitoid released field compared to the control.




[$T_1$= Cultural method (clean cultivation to keep the plot free from weeds and debris to discourage pupation of insect); + mechanical control method (removal of infested roots, shoots and fruits) at the 7 days interval $T_2$= Braconid wasps at the rate of 20-25/plot at weekly interval + field sanitation; $T_3$= Sanitation at the 7 days interval + using Funnel Pheromone trap; $T_4$= Field sanitation + Spraying Sevin 50 WP @ 1.0g/ at the 7 days interval; $T_5$= Spraying Success 2.5 EC @ 0.5 ml/L of water at the 7 days interval + using Pheromone trap; $T_6$= Spraying Spinosad 45% SC @ 0.01% at 20 days interval + using Funnel Pheromone trap; $T_7$= Sanitation + *Trichogramma evanesence* at the rate of 1 card/plot at weekly interval (1000 eggs per card) $T_8$= Untreated control]

**Figure 1.** Infestation of brinjal shoot caused by the brinjal shoot and fruit borer (BSFB) in different treatments at 55 DAT.

**At 70 DAT**

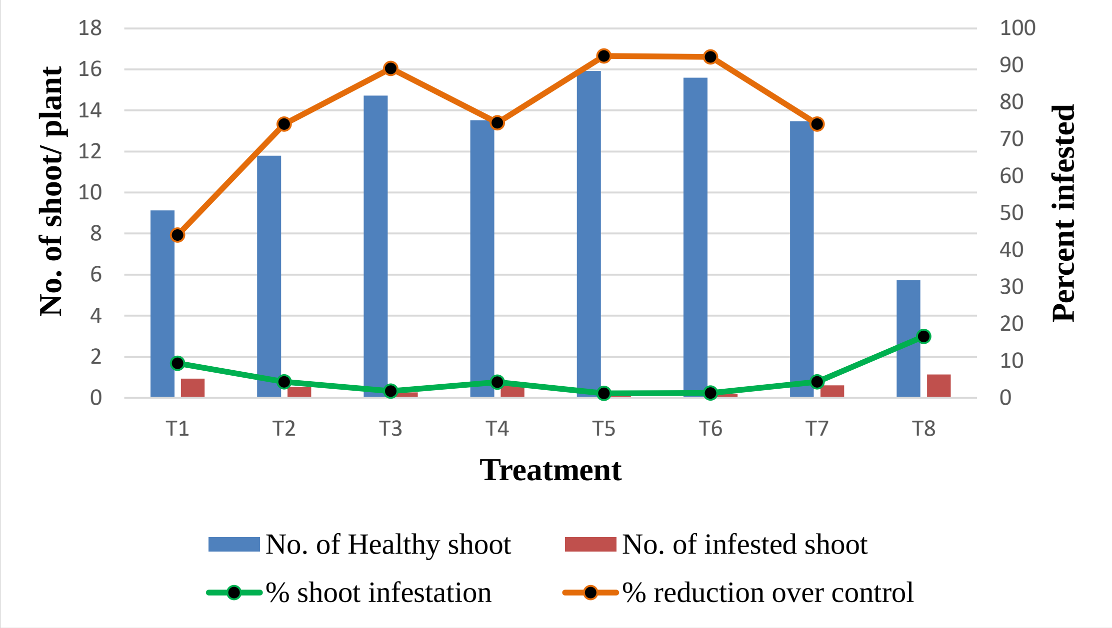
Number of healthy and infested shoots, infestation percentage showed statistically significant differences due to different bio-rational based management practices as treatments in controlling brinjal shoot and fruit borer at 70 DAT (Figure 2).

The highest number of healthy shoots plant$^{-1}$ (15.93) was recorded from $T_5$ (spraying success 2.5 EC @0.5 ml/L of water + using pheromone trap) treatment which was statistically similar with (15.60 and 14.73, respectively) to $T_6$ (Spraying Spinosad 45% SC @ 0.01% + using Funnel Pheromone trap) and $T_3$ (Sanitation at the 7 days interval + using Funnel Pheromone trap) treatment followed by $T_4$ (sanitation + Spraying Sevin 50 WP @ 1.0g/L at 7 days interval) (13.53) and $T_7$ (sanitation + *Trichogramma evanescens* at the rate of 1 card/plot) (13.47), whereas the lowest number of healthy shoots per plant (5.73) was found from $T_8$ (untreated control) treatment followed (9.13 and 11.80, respectively) by $T_1$ (cultural method + mechanical control method)and $T_2$ (Braconid wasps at the rate of 20-25/plot) treatment.

The lowest number of infested shoots plant$^{-1}$ (0.20) was recorded from $T_5$ and $T_6$ treatment which were statistically similar with $T_3$ (0.27) and closely followed by $T_2$ (0.53), $T_4$ (0.60) and $T_7$ (0.60) treatment. On the other hand, the highest number of infested shoots was obtained from $T_8$ (1.13) treatment which was statistically similar (0.93) with $T_1$ treatment.

Considering the percentage (%) of shoots infestation, the lowest infested shoots plant$^{-1}$ in number was recorded from $T_5$ (1.24%) which was statistically similar to $T_6$ (1.28%) followed (1.80%, 4.26%, 4.31% and 4.32%, respectively) by $T_3$, $T_4$, $T_2$ and $T_7$ treatment; the maximum infested shoots were recorded in $T_8$ (16.65%) which was statistically different from rest of the treatment.

Infestation of shoot reduction over control in number was estimated and the maximum value was found from the treatment $T_5$ (92.55%) followed by (92.31 %, 89.19%, 74.41%, 74.11% and 74.05%, respectively) from the treatment $T_6$, $T_3$, $T_4$, $T_2$ and $T_7$ and the minimum reduction of shoot infestation over control (44.08%) from $T_1$ treatment.




[$T_1$= Cultural method (clean cultivation to keep the plot free from weeds and debris to discourage pupation of insect); + mechanical control method (removal of infested roots, shoots and fruits) at the 7 days interval $T_2$= Braconid wasps at the rate of 20-25/plot at weekly interval + field sanitation; $T_3$= Sanitation at the 7 days interval + using Funnel Pheromone trap; $T_4$= Field sanitation + Spraying Sevin 50 WP @ 1.0g/ at the 7 days interval; $T_5$= Spraying Success 2.5 EC @ 0.5 ml/L of water at the 7 days interval + using Pheromone trap; $T_6$= Spraying Spinosad 45% SC @ 0.01% at 20 days interval + using Funnel Pheromone trap; $T_7$= Sanitation + *Trichogramma evanesence* at the rate of 1 card/plot at weekly interval (1000 eggs per card) $T_8$= Untreated control]

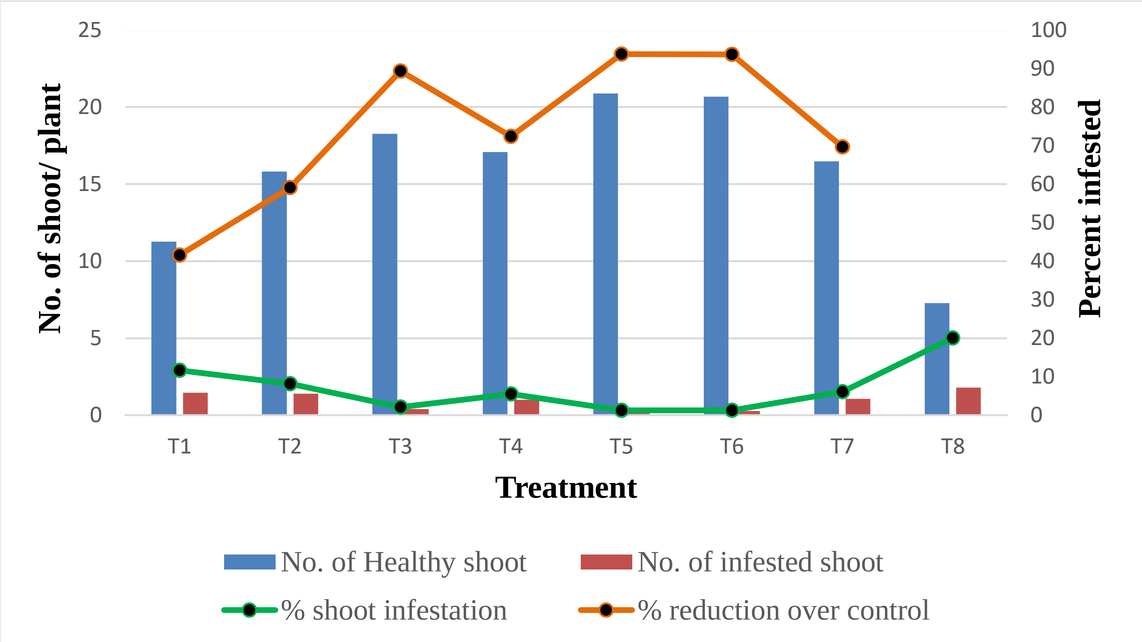
**Figure 2.** Infestation of brinjal shoot caused by the brinjal shoot and fruit borer (BSFB) in different treatments at 70 DAT

**At 85 DAT**

Number of healthy and infested shoots, infestation percentage showed statistically significant differences due to different bio-rational based management practices as treatments in controlling brinjal shoot and fruit borer at 85 DAT (Figure 3).

The highest number of healthy shoots plant$^{-1}$ (20.87) was recorded from $T_5$ (spraying success 2.5 EC @0.5 ml/L of water + using pheromone trap) treatment which was statistically similar to (20.67) $T_6$ (Spraying Spinosad 45% SC @ 0.01% + using Funnel Pheromone trap) treatment and (18.27) $T_3$ (Sanitation at the 7 days interval + using Funnel Pheromone trap) treatment and followed by (17.07, 16.47, 15.80 and 11.27) $T_4$ (Field sanitation + Spraying Sevin 50 WP @ 1.0g/L of water), $T_7$ (Sanitation + *Trichogramma evanescens* at the rate of 1 card/plot), $T_2$ (Braconid wasps at the rate of 20-25/plot) and $T_1$ (cultural method + mechanical control method) treatment, respectively. Whereas the lowest number of healthy shoots plant$^{-1}$ (7.27) was found from $T_8$ (untreated control) treatment.

The lowest number of infested shoots plant$^{-1}$ (0.27) was recorded from $T_5$ treatment and $T_6$ treatment which were statistically similar with $T_3$ (0.40) treatment and closely followed by (1.07 and 1.0) $T_4$ and $T_7$ treatment, respectively. On the other hand, the highest number of infested shoots was obtained from $T_8$ (1.80) treatment followed by $T_1$ (1.47) treatment.




[$T_1$= Cultural method (clean cultivation to keep the plot free from weeds and debris to discourage pupation of insect); + mechanical control method (removal of infested roots, shoots and fruits) at the 7 days interval $T_2$= Braconid wasps at the rate of 20-25/plot at weekly interval + field sanitation; $T_3$= Sanitation at the 7 days interval + using Funnel Pheromone trap; $T_4$= Field sanitation + Spraying Sevin 50 WP @ 1.0g/ at the 7 days interval; $T_5$= Spraying Success 2.5 EC @ 0.5 ml/L of water at the 7 days interval + using Pheromone trap; $T_6$= Spraying Spinosad 45% SC @ 0.01% at 20 days interval + using Funnel Pheromone trap; $T_7$= Sanitation + *Trichogramma evanesence* at the rate of 1 card/plot at weekly interval (1000 eggs per card) $T_8$= Untreated control]

**Figure 3.** Infestation of brinjal shoot caused by the brinjal shoot and fruit borer (BSFB) in different treatments at 85 DAT

In relation to the percentage (%) of shoots infestation, the lowest infested shoots per plant in number was recorded from $T_5$ (1.26%) which was statistically similar to $T_6$ (1.28%) treatment followed (2.14%, 5.53%, 6.08% and 8.18%) by $T_3$, $T_4$, $T_7$ and $T_2$ treatment, respectively. The maximum infested shoots were recorded in $T_8$ (20.01%) followed by $T_1$ treatment (11.69%).

Infestation of shoot reduction over control in number was recorded and the highest value was recorded from the treatment $T_5$ (93.70%) followed by $T_6$ (93.60%), $T_3$ (89.31%) and $T_4$ (72.36%) treatments and the minimum reduction of shoot infestation over control from $T_1$ (41.58%) followed by $T_2$ (59.12%) and $T_7$ (69.62%) treatment.

**At 100 DAT**

Number of healthy and infested shoot, infestation percentage showed statistically significant differences due to different bio-rational based management as treatments in controlling brinjal shoot and fruit borer of brinjal (Figure 4) at 100 DAT.

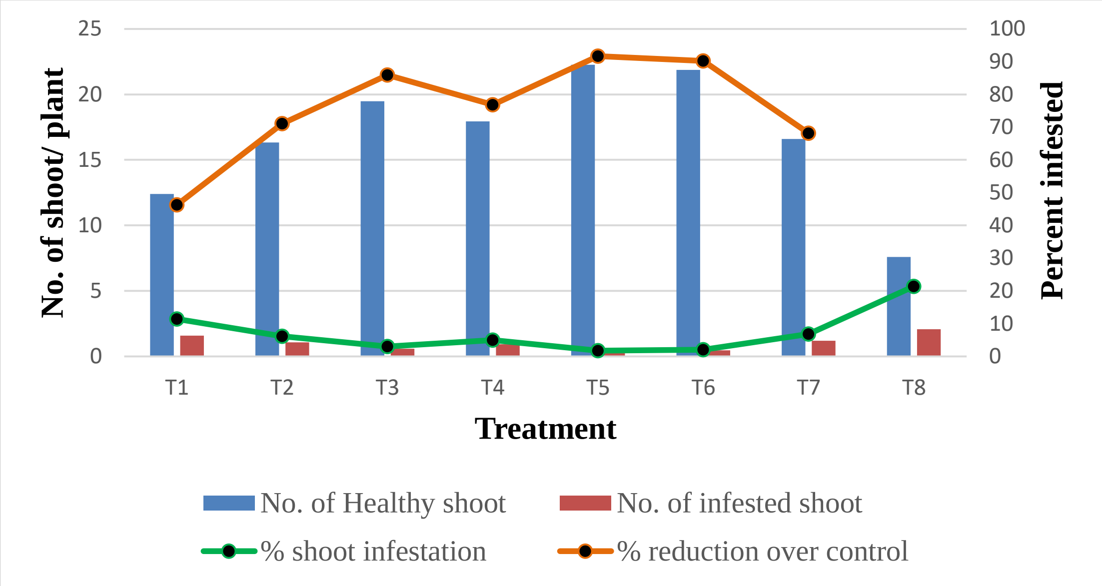
The highest number of healthy shoots per plant (22.27) was recorded from $T_5$ (Spraying Success 2.5 EC @ 0.5 ml/L of water) treatment which was statistically similar (21.87 and 19.47, respectively) with $T_6$ (Spraying Spinosad 45% SC @ 0.01%) and $T_3$ (Sanitation at the 7 days interval + using Funnel Pheromone trap) treatment and closely followed by (17.93, 16.60, 16.33 and 12.40) $T_4$ (Field sanitation + Spraying Sevin 50 WP @ 1.0g/L of water), $T_7$ (Sanitation + Trichogramma evanesence at the rate of 1 card/plot), $T_2$ (Trichogramma chilonis at the rate of 1 card/plot + field sanitation) and $T_1$ (Cultural + mechanical control method) treatment, respectively. Whereas the lowest number of healthy shoots per plant (7.60) was found from $T_8$ (untreated control) treatment.

The lowest number of infested shoots per plant was obtained from $T_5$ (0.40) treatment which was statistically similar to $T_6$ (0.47) treatment and different from $T_3$ (0.60), $T_4$ (0.93), $T_2$ (1.07) and $T_7$ (1.20) treatment. On the other hand, the highest number of infested shoots was obtained from $T_8$ (2.07) treatment followed by $T_1$ (1.60) treatment.

In relation to the percentage (%) of shoot infestation, the lowest infested shoots per plant in number was recorded from $T_5$ (1.78%) which was statistically similar with $T_6$ (2.10%) and $T_3$ (3.0%), again the maximum infested shoots were recorded in $T_8$ (21.36%).

Infestation of shoot reduction over control in number was estimated and the highest value was found from the treatment $T_5$ (91.67%) which was followed by

$T_6$ (90.17%), $T_3$ (85.96%), $T_4$ (76.83%) and $T_2$ (71.11%) treatments and the minimum reduction of shoot infestation over control from $T_1$ (46.25%) treatment followed by $T_7$ (68.16 %).




[$T_1$= Cultural method (clean cultivation to keep the plot free from weeds and debris to discourage pupation of insect); + mechanical control method (removal of infested roots, shoots and fruits) at the 7 days interval $T_2$= Braconid wasps at the rate of 20-25/plot at weekly interval + field sanitation; $T_3$= Sanitation at the 7 days interval + using Funnel Pheromone trap; $T_4$= Field sanitation + Spraying Sevin 50 WP @ 1.0g/ at the 7 days interval; $T_5$= Spraying Success 2.5 EC @ 0.5 ml/L of water at the 7 days interval + using Pheromone trap; $T_6$= Spraying Spinosad 45% SC @ 0.01% at 20 days interval + using Funnel Pheromone trap; $T_7$= Sanitation + *Trichogramma evanesence* at the rate of 1 card/plot at weekly interval (1000 eggs per card) $T_8$= Untreated control]

**Figure 4:** Infestation of brinjal shoot caused by the brinjal shoot and fruit borer (BSFB) in different treatments at 100 DAT.

**At 115 DAT**

Number of healthy and infested shoot, infestation percentage showed statistically significant differences due to different bio-rational based management as treatments in controlling brinjal shoot and fruit borer (Figure 5) at 115 DAT.

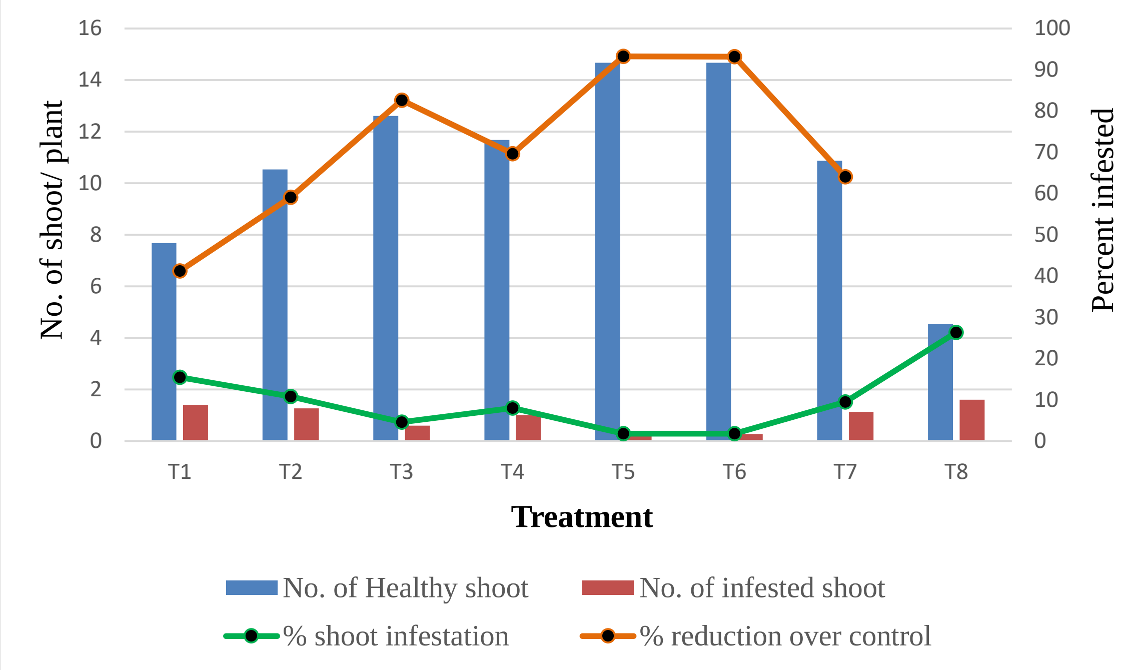
The highest number of healthy shoots per plant (14.67) was recorded from $T_5$ (Spraying Success 2.5 EC @ 0.5 ml/L of water) and $T_6$ (Spraying Spinosad 45% SC @ 0.01%) treatment which was statistically similar with (12.60) to $T_3$ (Sanitation at the 7 days interval + using Funnel Pheromone trap) treatment and closely followed by (11.67, 10.87, 10.53 and 7.67) $T_4$ (Field sanitation + Spraying Sevin 50 WP @ 1.0g/L of water), $T_7$ (Sanitation + Trichogramma evanesence at the rate of 1 card/plot), $T_2$ (Trichogramma chilonis at the rate of 1 card/plot + field sanitation) and $T_1$ (Cultural + mechanical control method) treatment, respectively. Whereas the lowest number of healthy shoots per plant 4.53 was found from $T_8$ (untreated control) treatment.

The lowest number of infested shoots per plant (0.27) was obtained from $T_5$ and $T_6$ treatment which was showed statistically differences from $T_3$ (0.60), $T_4$ (1.0), $T_7$ (1.13) and $T_2$ (1.27) treatment. On the other hand, the highest number of infested shoots was obtained from $T_8$ (1.60) treatment followed by $T_1$ (1.40) treatment.

In relation to the percentage of shoot infestation, the lowest infested shoots per plant in number was recorded from $T_5$ (1.79%) which was statistically similar with $T_6$ (1.80%) and $T_3$ (4.58%), again the maximum infested shoots were recorded in $T_8$ (26.31%) followed by $T_1$ (15.47 %).

Infestation of shoot reduction over control in number was estimated and the highest value was found from the treatment $T_5$ (93.20%) which was followed by $T_6$ (93.16%), $T_3$ (82.59%), $T_4$ (69.63 %) and $T_7$ (64.04%) treatments and the minimum reduction of shoot infestation over control from $T_1$ (41.20 %) treatment followed by $T_2$ (59.10%) treatment.

This result showed conformity with the findings of Mathur *et al.* (2012) that sex pheromones is one of the most important methods in controlling *L. orbonalis* and it was also concluded that the use of pheromone traps was found effective in reducing shoot damage and fruit infestation with 46.15% and 25.6% percent protection over control, respectively.




[$T_1$= Cultural method (clean cultivation to keep the plot free from weeds and debris to discourage pupation of insect); + mechanical control method (removal of infested roots, shoots and fruits) at the 7 days interval $T_2$= Braconid wasps at the rate of 20-25/plot at weekly interval + field sanitation; $T_3$= Sanitation at the 7 days interval + using Funnel Pheromone trap; $T_4$= Field sanitation + Spraying Sevin 50 WP @ 1.0g/ at the 7 days interval; $T_5$= Spraying Success 2.5 EC @ 0.5 ml/L of water at the 7 days interval + using Pheromone trap; $T_6$= Spraying Spinosad 45% SC @ 0.01% at 20 days interval + using Funnel Pheromone trap; $T_7$= Sanitation + *Trichogramma evanesence* at the rate of 1 card/plot at weekly interval (1000 eggs per card) $T_8$= Untreated control]

**Figure 5.** Infestation of brinjal shoot caused by the brinjal shoot and fruit borer (BSFB) in different treatments at 115 DAT

## 4.2. Effect of different treatments on flower infestation of brinjal at different days after transplanting (DAT)

### At 55 DAT

Number of healthy and infested flowers, infestation percentage at flowering stage showed statistically significant differences due to different bio-rational based management practices as treatments in controlling brinjal shoot and fruit borer at 55 DAT (Table 1).

The highest number of healthy flowers per plant (13.33) was recorded from $T_5$ (spraying success 2.5 EC @ 0.5 ml/L of water + using pheromone trap) treatment which was statistically different from rest of the treatment except $T_6$ (Spraying Spinosad 45% SC @ 0.01% + using Funnel Pheromone trap), whereas the lowest number of healthy flowers per plant (5.0) was found from $T_8$ (untreated control) treatment followed by $T_1$ (cultural method + mechanical control method) (6.60), $T_2$ (Braconid wasps @ 20-25/plot) (9.0), $T_7$ (Sanitation + *Trichogramma evanescens* at the rate of 1 card/plot (1000 eggs per card) (9.33), $T_3$ (Sanitation + using Funnel Pheromone trap) (10.60) and $T_4$ (Field sanitation + Spraying Sevin 50 WP @ 1.0g/L of water) (10.67) treatment.

The lowest number of infested flowers per plant (1.0) was obtained from $T_5$ treatment which was statistically similar to $T_6$ (1.13) treatment and followed by $T_4$ (1.60), $T_3$ (1.67) and $T_1$ (1.67) treatment and they were statistically similar. On the other hand, the highest number of infested flowers was obtained from $T_8$ (2.33) treatment which was followed by $T_7$ (2.07) and $T_2$ (1.93) treatment.

**Table 1: Infestation of brinjal flower caused by the brinjal shoot and fruit borer (BSFB) in different treatments at 55 DAT**

| Treatment | Brinjal flower by number at 55 DAT | | | |
|---|---|---|---|---|
| | No. of Healthy flower | No. of infested flower | % flower infestation | % reduction over control |
| **$T_1$** | 6.60 d | 1.67 c | 20.29 b | 36.38 |
| **$T_2$** | 9.00 c | 1.93 bc | 17.80 b | 44.18 |
| **$T_3$** | 10.60 b | 1.67 c | 13.72 c | 56.98 |
| **$T_4$** | 10.67 b | 1.60 c | 13.05 c | 59.08 |
| **$T_5$** | 13.33 a | 1.00 d | 6.98 d | 78.11 |
| **$T_6$** | 13.33 a | 1.13 d | 7.85 d | 75.38 |
| **$T_7$** | 9.33 c | 2.07 ab | 18.16 b | 43.05 |
| **$T_8$** | 5.00 e | 2.33 a | 31.89 a | -- |
| **$LSD_{(0.05)}$** | 0.84 | 0.36 | 3.26 | -- |
| **CV(%)** | 4.92 | 12.38 | 11.48 | -- |

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability with 3 replications.

[$T_1$= Cultural method (clean cultivation to keep the plot free from weeds and debris to discourage pupation of insect); + mechanical control method (removal of infested roots, shoots and fruits) at the 7 days interval $T_2$= Braconid wasps at the rate of 20-25/plot at weekly interval + field sanitation; $T_3$= Sanitation at the 7 days interval + using Funnel Pheromone trap; $T_4$= Field sanitation + Spraying Sevin 50 WP @ 1.0g/ at the 7 days interval; $T_5$= Spraying Success 2.5 EC @ 0.5 ml/L of water at the 7 days interval + using Pheromone trap; $T_6$= Spraying Spinosad 45% SC @ 0.01% at 20 days interval + using Funnel Pheromone trap; $T_7$= Sanitation + *Trichogramma evanesence* at the rate of 1 card/plot at weekly interval (1000 eggs per card) $T_8$= Untreated control]

In relation to the percentage (%) of flowers infestation, the lowest infested flowers per plant in number was recorded from $T_5$ (6.98%) which was statistically similar to $T_6$ (7.85%) and followed by $T_4$ (13.05%) and $T_3$ (13.72%); again the maximum infested flowers were recorded in $T_8$ (31.89%) which was statistically different from rest of the treatment.

Infestation of flower reduction over control in number was estimated and the highest value was found from the treatment $T_5$ (78.11%) followed by $T_6$ (75.38 %), $T_4$ (59.08%) and $T_3$ (56.98%) treatments and the minimum reduction of flower infestation over control from $T_1$ (36.38%) followed by $T_7$ (43.05%) and $T_2$ (44.18%) treatment.

**At 70 DAT**

From Table 2, it was showed that at 70 DAT the highest number of healthy flowers per plant (26.73) was recorded from $T_5$ (spraying success 2.5 EC @ 0.5 ml/L of water + using pheromone trap) treatment which was statistically similar to $T_6$ (Spraying Spinosad 45% SC @ 0.01% + using Funnel Pheromone trap) (26.07) and closely followed by $T_4$ (Field sanitation + Spraying Sevin 50 WP @ 1.0g/L) (22.13), $T_3$ (Sanitation + using Funnel Pheromone trap) (21.07), $T_7$ (Sanitation + *Trichogramma evanescens* @ 1 card/plot) (19.40) and $T_2$ (Braconid wasps @ 20-25/plot) (18.40), whereas the lowest number of healthy flowers per plant (10.67) was found from $T_8$ (untreated control) treatment followed by $T_1$ (cultural method + mechanical control method) (14.40).

The lowest number of infested flowers per plant (2.67) was obtained from $T_6$ treatment which showed statistically similarity with $T_5$ (2.73) treatment and statistically different from the treatment $T_4$ (3.67), $T_3$ (4.0), $T_7$ (4.60) and $T_2$ (4.80) treatment. On the other hand, the highest number of infested flowers was obtained from $T_8$ (6.07) treatment followed by $T_1$ (5.33).

In terms of percentage of flowers infestation, the lowest infested flowers per plant in number was recorded from $T_6$ (9.28%) which was statistically similar to $T_5$ (9.34%) and followed by $T_4$ (14.24%), $T_3$ (16.04%) and $T_7$ (19.17%). The maximum infested flowers were recorded in $T_8$ (36.35%) followed by $T_1$ (27.08%) and $T_2$ (20.77%).

Infestation of flower reduction over control in number was estimated and the highest value was found from the treatment $T_6$ (74.47%) followed by $T_5$ (74.31%), $T_4$ (60.83%) and $T_3$ (55.87%) treatment and the minimum reduction of flower infestation over control from $T_1$ (25.50%) followed by $T_2$ (42.86%) and $T_7$ (47.26%) treatment.

**Table 2. Infestation of brinjal flower caused by the brinjal shoot and fruit borer (BSFB) in different treatments at 70 DAT**

| Treatment | Brinjal flower by number at 70 DAT | | | |
|---|---|---|---|---|
| | No. of Healthy flower | No. of infested flower | % flower infestation | % reduction over control |
| **$T_1$** | 14.40 d | 5.33 ab | 27.08 b | 25.50 |
| **$T_2$** | 18.40 c | 4.80 bc | 20.77 c | 42.86 |
| **$T_3$** | 21.07 bc | 4.00 cd | 16.04 de | 55.87 |
| **$T_4$** | 22.13 b | 3.67 de | 14.24 e | 60.83 |
| **$T_5$** | 26.73 a | 2.73 ef | 9.34 f | 74.31 |
| **$T_6$** | 26.07 a | 2.67 f | 9.28 f | 74.47 |
| **$T_7$** | 19.40 bc | 4.60 bcd | 19.17 cd | 47.26 |
| **$T_8$** | 10.67 e | 6.07 a | 36.35 a | -- |
| **$LSD_{(0.05)}$** | 3.49 | 0.98 | 4.71 | -- |
| **CV(%)** | 10.04 | 13.20 | 14.12 | -- |

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability with 3 replications.

[$T_1$= Cultural method (clean cultivation to keep the plot free from weeds and debris to discourage pupation of insect); + mechanical control method (removal of infested roots, shoots and fruits) at the 7 days interval $T_2$= Braconid wasps at the rate of 20-25/plot at weekly interval + field sanitation; $T_3$= Sanitation at the 7 days interval + using Funnel Pheromone trap; $T_4$= Field sanitation + Spraying Sevin 50 WP @ 1.0g/ at the 7 days interval; $T_5$= Spraying Success 2.5 EC @ 0.5 ml/L of water at the 7 days interval + using Pheromone trap; $T_6$= Spraying Spinosad 45% SC @ 0.01% at 20 days interval + using Funnel Pheromone trap; $T_7$= Sanitation + *Trichogramma evanesence* at the rate of 1 card/plot at weekly interval (1000 eggs per card) $T_8$= Untreated control]

**At 85 DAT**

Number of healthy and infested flower, infestation percentage at flowering stage showed statistically significant differences due to different bio-rational management as treatments in controlling brinjal shoot and fruit borer of brinjal (Table 3) at 85 DAT.

The highest number of healthy flowers per plant (34.07) was recorded from $T_5$ (Spraying Success 2.5 EC @ 0.5 ml/L of water) treatment which was statistically similar with (33.53) to $T_6$ (Spraying Spinosad 45% SC @ 0.01%) treatment and closely followed by (28.40, 27.40, 25.73 and 24.73) $T_4$ (Field sanitation + Spraying Sevin 50 WP @ 1.0g/L), $T_3$ (Sanitation at the 7 days interval + using Funnel Pheromone trap), $T_7$ (Sanitation + *Trichogramma evanescens* at the rate of 1 card/plot) and $T_2$ (Braconid wasps @ 20-25/plot), respectively and they were statistically similar, whereas the lowest number of healthy flowers per plant (15.07) was found from $T_8$ (untreated control) treatment followed (20.40) by $T_1$ (Cultural method + mechanical control method) treatment.

The lowest number of infested flowers per plant was obtained from $T_6$ (4.27) treatment which was statistically similar to $T_5$ (4.40) treatment and closely followed by $T_4$ (5.47), $T_3$ (6.0) $T_7$ (6.73) and $T_2$ (6.93) treatment. On the other hand, the highest number of infested flowers was obtained from $T_8$ (9.67) treatment which was followed by $T_1$ (8.40) treatment.

In relation to the percentage of flower infestation, the lowest infested flowers per plant in number was recorded from $T_6$ (11.29%) which was statistically similar to $T_5$ (11.48%) and $T_4$ (16.39%), again the maximum infested fruits were recorded in $T_8$ (39.15%)

Infestation of flower reduction over control in number was estimated and the highest value was found from the treatment $T_6$ (71.16%) which was followed by $T_5$ (70.68%), $T_4$ (58.14%) and $T_3$ (53.90%) and the minimum reduction of flower infestation over control from $T_1$ (25.34%) followed by $T_2$ (43.93%) and $T_7$ (46.95%).

**Table 3. Infestation of brinjal flower caused by the brinjal shoot and fruit borer (BSFB) in different treatments at 85 DAT**

| Treatment | Brinjal flower by number at 85 DAT | | | |
|---|---|---|---|---|
| | No. of healthy flower | No. of infested flower | % flower infestation | % reduction over control |
| **$T_1$** | 20.40 c | 8.40 ab | 29.23 b | 25.34 |
| **$T_2$** | 24.73 bc | 6.93 bc | 21.95 c | 43.93 |
| **$T_3$** | 27.40 b | 6.00 c | 18.05 c | 53.90 |
| **$T_4$** | 28.40 b | 5.47 cd | 16.39 cd | 58.14 |
| **$T_5$** | 34.07 a | 4.40 d | 11.48 d | 70.68 |
| **$T_6$** | 33.53 a | 4.27 d | 11.29 d | 71.16 |
| **$T_7$** | 25.73 b | 6.73 c | 20.77 c | 46.95 |
| **$T_8$** | 15.07 d | 9.67 a | 39.15 a | -- |
| **$LSD_{(0.05)}$** | 4.97 | 1.52 | 5.65 | -- |
| **CV(%)** | 10.84 | 13.36 | 15.34 | -- |

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability with 3 replications.

[$T_1$= Cultural method (clean cultivation to keep the plot free from weeds and debris to discourage pupation of insect); + mechanical control method (removal of infested roots, shoots and fruits) at the 7 days interval $T_2$= Braconid wasps at the rate of 20-25/plot at weekly interval + field sanitation; $T_3$= Sanitation at the 7 days interval + using Funnel Pheromone trap; $T_4$= Field sanitation + Spraying Sevin 50 WP @ 1.0g/ at the 7 days interval; $T_5$= Spraying Success 2.5 EC @ 0.5 ml/L of water at the 7 days interval + using Pheromone trap; $T_6$= Spraying Spinosad 45% SC @ 0.01% at 20 days interval + using Funnel Pheromone trap; $T_7$= Sanitation + *Trichogramma evanesence* @ 1 card/plot at weekly interval (1000 eggs per card) $T_8$= Untreated control]

### At 100 DAT

Number of healthy and infested flower, infestation percentage at flowering stage showed statistically significant differences due to different bio-rational based management as treatments in controlling brinjal shoot and fruit borer of brinjal at 100 DAT (Table 4).

The highest number of healthy flowers per plant (28.73) was recorded from $T_5$ (Spraying Success 2.5 EC @ 0.5 ml/L of water) treatment which was statistically similar (28.07 and 24.07, respectively) with $T_6$ (Spraying Spinosad 45% SC @

0.01%) and $T_4$ (Field sanitation + Spraying Sevin 50 WP @ 1.0g/L) treatment and closely followed (23.40, 21.73 and 21.07) by $T_3$ (Sanitation at the 7 days interval + using Funnel Pheromone trap), $T_7$ (Sanitation + *Trichogramma evanescens*) at the rate of 1 card/plot) and $T_2$ (Braconid wasps @ 20-25/plot), respectively and they were statistically similar, whereas the lowest number of healthy flowers per plant (12.67) was found from $T_8$ (untreated control) treatment followed by (17.40) $T_1$ (Cultural method + mechanical control method) treatment.

**Table 4. Infestation of brinjal flower caused by the brinjal shoot and fruit borer (BSFB) in different treatments at 100 DAT**

| Treatment | Brinjal flower by number at 100 DAT | | | |
|---|---|---|---|---|
| | No. of Healthy flower | No. of infested flower | % flower infestation | % reduction over control |
| **$T_1$** | 17.40 de | 7.07 a | 28.98 b | 24.73 |
| **$T_2$** | 21.07 cd | 5.73 b | 21.61 c | 43.87 |
| **$T_3$** | 23.40 bc | 4.80 bc | 17.04 cd | 55.74 |
| **$T_4$** | 24.07 abc | 4.33 cd | 15.31 de | 60.23 |
| **$T_5$** | 28.73 a | 3.03 e | 9.65 f | 74.94 |
| **$T_6$** | 28.07 ab | 3.47 de | 11.08 ef | 71.22 |
| **$T_7$** | 21.73 cd | 5.00 bc | 18.86 cd | 51.01 |
| **$T_8$** | 12.67 e | 7.93 a | 38.50 a | -- |
| **$LSD_{(0.05)}$** | 4.89 | 1.20 | 5.13 | -- |
| **CV(%)** | 12.62 | 13.30 | 14.55 | -- |

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability with 3 replications.

[$T_1$= Cultural method (clean cultivation to keep the plot free from weeds and debris to discourage pupation of insect); + mechanical control method (removal of infested roots, shoots and fruits) at the 7 days interval $T_2$= Braconid wasps at the rate of 20-25/plot at weekly interval + field sanitation; $T_3$= Sanitation at the 7 days interval + using Funnel Pheromone trap; $T_4$= Field sanitation + Spraying Sevin 50 WP @ 1.0g/ at the 7 days interval; $T_5$= Spraying Success 2.5 EC @ 0.5 ml/L of water at the 7 days interval + using Pheromone trap; $T_6$= Spraying Spinosad 45% SC @ 0.01% at 20 days interval + using Funnel Pheromone trap; $T_7$= Sanitation + *Trichogramma evanesence* at the rate of 1 card/plot at weekly interval (1000 eggs per card) $T_8$= Untreated control]

The lowest number of infested flowers per plant was obtained from $T_5$ (3.03) treatment which was statistically similar to $T_6$ (3.47) treatment and closely followed by $T_4$ (4.33), $T_3$ (4.80), $T_7$ (5.0) and $T_2$ (5.73) treatment. On the other hand, the highest number of infested flowers was obtained from $T_8$ (7.93) treatment which was followed by $T_1$ (7.07) treatment.

In case of the percentage of flower infestation, the lowest infested flowers per plant in number was recorded from $T_5$ (9.65%) which showed statistically differences from rest of the treatment except $T_6$ (11.08%), and the maximum infested flowers were recorded in $T_8$ tratment (38.50%).

Infestation of flower reduction over control in number was estimated and the highest value was found from the treatment $T_5$ (74.94%) followed by $T_6$ (71.22%), $T_4$ (60.23%), $T_3$ (55.74%), $T_7$ (51.01%) and $T_2$ (43.87%) treatments and the minimum reduction of flower infestation over control from $T_1$ (24.73%) treatment.

**At 115 DAT**

Number of healthy and infested flower, infestation percentage at flowering stage showed statistically significant differences due to different bio-rational based management as treatments in controlling brinjal shoot and fruit borer of brinjal (Table 5) at 115 DAT.

The highest number of healthy flowers per plant (22.40) was recorded from $T_5$ (Spraying Success 2.5 EC @ 0.5 ml/L of water) and $T_6$ (Spraying Spinosad 45% SC @ 0.01%) treatment and closely followed (18.40, 17.73, 16.07 and 15.40) by $T_4$ (Field sanitation + Spraying Sevin 50 WP @ 1.0g/L), $T_3$ (Sanitation at the 7 days interval + using Funnel Pheromone trap), $T_7$ (Sanitation + *Trichogramma evanesence* at the rate of 1 card/plot) and $T_2$ (Braconid wasps at the rate of 20-25/plot) and they were statistically similar, whereas the lowest number of healthy flowers per plant (7.0) was found from $T_8$ (untreated control) treatment followed (11.0) by $T_1$ (Cultural method + mechanical control method) treatment.

The lowest number of infested flowers per plant was obtained from $T_5$ (2.0) treatment which was statistically similar to $T_6$ (2.07) treatment and closely followed by $T_4$ (2.93), $T_3$ (3.33) $T_7$ (3.40) and $T_2$ (4.0) treatment. On the other hand, the highest number of infested flowers was obtained from $T_8$ (5.33) treatment which was followed by $T_1$ (4.73).

In relation to the percentage of flower infestation, the lowest infested flowers per plant in number was recorded from $T_6$ (8.51%) which was statistically similar to $T_5$ (8.26%) and followed by $T_4$ (13.87%), $T_3$ (15.80%), $T_7$ (17.48%) and $T_2$ (20.59%) and the maximum infested fruits were recorded in $T_8$ (43.28%) followed by $T_1$ (30.23%) treatment.

Infestation of flower reduction over control in number was estimated and the highest value was found from the treatment $T_5$ (80.91%) statistically similar with $T_6$ (80.34%) and followed by $T_4$ (67.95%) and $T_3$ (63.49%) treatments and the minimum reduction of flower infestation over control from $T_1$ (30.15%) followed by $T_2$ (52.43%) and $T_7$ (59.61%) treatments, respectively.

**Table. 5. Infestation of brinjal flower caused by the brinjal shoot and fruit borer (BSFB) in different treatments at 115 DAT**

| Treatment | Brinjal flower by number at 115 DAT | | | |
|---|---|---|---|---|
| | No. of Healthy flower | No. of infested flower | % flower infestation | % reduction over control |
| $T_1$ | 11.00 d | 4.73 a | 30.23 b | 30.15 |
| $T_2$ | 15.40 c | 4.00 b | 20.59 c | 52.43 |
| $T_3$ | 17.73 bc | 3.33 bc | 15.80 d | 63.49 |
| $T_4$ | 18.40 b | 2.93 c | 13.87 d | 67.95 |
| $T_5$ | 22.40 a | 2.00 d | 8.26 e | 80.91 |
| $T_6$ | 22.40 a | 2.07 d | 8.51 e | 80.34 |
| $T_7$ | 16.07 bc | 3.40 bc | 17.48 cd | 59.61 |
| $T_8$ | 7.00 e | 5.33 a | 43.28 a | -- |
| $LSD_{(0.05)}$ | 2.51 | 0.70 | 3.79 | -- |
| CV(%) | 8.81 | 11.45 | 10.96 | -- |

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability with 3 replications.

[$T_1$= Cultural method (clean cultivation to keep the plot free from weeds and debris to discourage pupation of insect); + mechanical control method (removal of infested roots, shoots and fruits) at the 7 days interval $T_2$= Braconid wasps at the rate of 20-25/plot at weekly interval + field sanitation; $T_3$= Sanitation at the 7 days interval + using Funnel Pheromone trap; $T_4$= Field sanitation + Spraying Sevin 50 WP @ 1.0g/ at the 7 days interval; $T_5$= Spraying Success 2.5 EC @ 0.5 ml/L of water at the 7 days interval + using Pheromone trap; $T_6$= Spraying Spinosad 45% SC @ 0.01% at 20 days interval + using Funnel Pheromone trap; $T_7$= Sanitation + *Trichogramma evanesence* at the rate of 1 card/plot at weekly interval (1000 eggs per card) $T_8$= Untreated control]

### 4.3. Effect of different treatments on fruit infestation of brinjal in number at different days after transplanting (DAT)

**At 88 DAT**

Number of healthy and infested fruit, infestation percentage at fruit setting stage showed statistically significant differences due to different bio-rational based managements as treatments in controlling brinjal shoot and fruit borer of brinjal at 88 DAT (Table 6).

The highest number of healthy fruits (8.67) was recorded from $T_5$ (Spraying Success 2.5 EC @ 0.5 ml/L of water) treatment which was statistically similar with (8.33, 7.33 and 7.33) $T_6$ (Spraying Spinosad 45% SC @ 0.01%), $T_4$ (Field sanitation + Spraying Sevin 50 WP @ 1.0g/L) and $T_7$ (Sanitation + *Trichogramma evanesence* at the rate of 1 card/plot) and closely followed (6.67 and 5.67) by $T_2$ (Braconid wasps at the rate of 20-25/plot) and $T_3$ (Sanitation at the 7 days interval + using Funnel Pheromone trap), respectively. The lowest number of healthy fruits (3.33) was found from $T_8$ (untreated control) treatment followed by (5.0) $T_1$ (Cultural method + mechanical control method) treatment.

The lowest number of infested fruits (0.67) was obtained from $T_5$ and $T_6$ treatment which was statistically similar to $T_3$ (2.00) treatment and closely followed (1.33) by $T_2$, $T_4$ and $T_7$ treatment. On the other hand, the highest number of infested fruits was obtained from $T_8$ (2.0) treatment which was statistically and numerically similar with $T_1$ and $T_3$ treatment.

In relation to the fruit infestation percentage, the lowest infested fruits in number was recorded from $T_5$ (7.24%) which was statistically similar to $T_6$ (7.45%) and followed by $T_7$ (15.41) and $T_4$ (15.57%), again the maximum infested fruits were recorded in $T_8$ (37.55%).

Infestation of fruit reduction over control (%) was estimated and the highest value was found from the treatment $T_5$ (80.72 %) which was followed by $T_6$ (80.16%), $T_7$ (58.96 %), $T_4$ (58.54 %) and $T_2$ (55.53 %) treatment and the minimum reduction of fruit infestation over control (%) from $T_1$ (23.83 %) followed by $T_3$ (30.15%) treatment.

**Table 6. Infestation of brinjal fruits caused by the brinjal shoot and fruit borer (BSFB) in different treatments at 88 DAT in number**

| Treatment | Brinjal fruit by number at 88 DAT | | | |
|---|---|---|---|---|
| | No. of Healthy fruit | No. of infested fruit | % fruit infestation | % reduction over control |
| $T_1$ | 5.00 d | 2.00 a | 28.60 b | 23.83 |
| $T_2$ | 6.67 bc | 1.33 b | 16.70 c | 55.53 |
| $T_3$ | 5.67 cd | 2.00 a | 26.23 b | 30.15 |
| $T_4$ | 7.33 ab | 1.33 b | 15.57 c | 58.54 |
| $T_5$ | 8.67 a | 0.67 c | 7.24 d | 80.72 |
| $T_6$ | 8.33 a | 0.67 c | 7.45 d | 80.16 |
| $T_7$ | 7.33 ab | 1.33 b | 15.41 c | 58.96 |
| $T_8$ | 3.33 e | 2.00 a | 37.55 a | -- |
| $LSD_{(0.05)}$ | 1.511 | 0.29 | 3.65 | -- |
| CV(%) | 13.19 | 11.56 | 10.79 | -- |

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability with 3 replications.

[$T_1$= Cultural method (clean cultivation to keep the plot free from weeds and debris to discourage pupation of insect); + mechanical control method (removal of infested roots, shoots and fruits) at the 7 days interval $T_2$= Braconid wasps at the rate of 20-25/plot at weekly interval + field sanitation; $T_3$= Sanitation at the 7 days interval + using Funnel Pheromone trap; $T_4$= Field sanitation + Spraying Sevin 50 WP @ 1.0g/ at the 7 days interval; $T_5$= Spraying Success 2.5 EC @ 0.5 ml/L of water at the 7 days interval + using Pheromone trap; $T_6$= Spraying Spinosad 45% SC @ 0.01% at 20 days interval + using Funnel Pheromone trap; $T_7$= Sanitation + *Trichogramma evanesence* at the rate of 1 card/plot at weekly interval (1000 eggs per card) $T_8$= Untreated control]

**At 95 DAT**

Number of healthy and infested fruit, infestation percentage at fruit setting stage showed statistically significant differences due to different bio-rational management as treatments in controlling brinjal shoot and fruit borer of brinjal at 95 DAT (Table 7).

The highest number of healthy fruits (13.33) was recorded from $T_5$ (Spraying Success 2.5 EC @ 0.5 ml/L of water) treatment which was statistically similar with (13.0) $T_6$ (Spraying Spinosad 45% SC @ 0.01%) and (11.67) $T_4$ (Field sanitation + Spraying Sevin 50 WP @ 1.0g/L) treatment and closely followed (11.0 and 10.0, respectively) by $T_7$ (Sanitation + *Trichogramma evanesence* @ 1 card/plot) and $T_2$ (Braconid wasps @ 20-25/plot) treatment and they were statistically similar, whereas the lowest number of healthy fruits (4.67) was found from $T_8$ (untreated control) treatment followed by (7.33) $T_1$ (Cultural method + mechanical control method) and (9.33) $T_3$ (Sanitation + using Funnel Pheromone trap) treatment.

The lowest number of infested fruits was obtained from $T_5$ (1.33) treatment which was statistically and numerically similar to $T_6$ treatment and closely followed by $T_4$, $T_2$, $T_3$, and $T_7$ treatment. On the other hand, the highest number of infested fruits was obtained from $T_8$ (4.33) treatment followed by $T_1$ (3.33) treatment.

In relation to the percentage (%) of fruit infestation, the lowest infested fruits in number was recorded from $T_5$ (9.20%) which was statistically different from rest of the treatment except $T_6$ (9.33%), again the maximum infested fruits were recorded in $T_8$ (48.17%) which was statistically different from $T_1$ (31.33 %), $T_3$ (20.14 %), $T_2$ (18.93 %) and $T_7$ (17.49 %).

Infestation of fruit reduction over control (%) was estimated and the highest value was found from the treatment $T_5$ (80.90%) which was followed by $T_6$ (80.63%), $T_4$ (69.28%), $T_7$ (63.69%) and $T_2$ (60.70%) and the minimum reduction of fruit infestation over control (%) was observed from $T_1$ (34.96%) followed by $T_3$ (58.19%) treatment.

**Table 7. Infestation of brinjal fruits caused by the brinjal shoot and fruit borer (BSFB) in different treatments at 95 DAT in number**

| Treatment | Brinjal fruit by number at 95 DAT | | | |
|---|---|---|---|---|
| | No. of Healthy fruit | No. of infested fruit | % fruit infestation | % reduction over control |
| $T_1$ | 7.33 e | 3.33 b | 31.33 b | 34.96 |
| $T_2$ | 10.00 cd | 2.33 c | 18.93 cd | 60.70 |
| $T_3$ | 9.33 de | 2.33 c | 20.14 c | 58.19 |
| $T_4$ | 11.67 abc | 2.00 c | 14.81 d | 69.28 |
| $T_5$ | 13.33 a | 1.33 d | 9.20 e | 80.90 |
| $T_6$ | 13.00 ab | 1.33 d | 9.33 e | 80.63 |
| $T_7$ | 11.00 bcd | 2.33 c | 17.49 cd | 63.69 |
| $T_8$ | 4.67 f | 4.33 a | 48.17 a | -- |
| $LSD_{(0.05)}$ | 2.19 | 0.49 | 4.91 | -- |
| CV(%) | 12.43 | 11.51 | 13.25 | -- |

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability with 3 replications.

[$T_1$= Cultural method (clean cultivation to keep the plot free from weeds and debris to discourage pupation of insect); + mechanical control method (removal of infested roots, shoots and fruits) at the 7 days interval $T_2$= Braconid wasps at the rate of 20-25/plot at weekly interval + field sanitation; $T_3$= Sanitation at the 7 days interval + using Funnel Pheromone trap; $T_4$= Field sanitation + Spraying Sevin 50 WP @ 1.0g/ at the 7 days interval; $T_5$= Spraying Success 2.5 EC @ 0.5 ml/L of water at the 7 days interval + using Pheromone trap; $T_6$= Spraying Spinosad 45% SC @ 0.01% at 20 days interval + using Funnel Pheromone trap; $T_7$= Sanitation + *Trichogramma evanesence* at the rate of 1 card/plot at weekly interval (1000 eggs per card) $T_8$= Untreated control]

### At 102 DAT

Number of healthy and infested fruit, infestation percentage at fruit setting stage showed statistically significant differences due to different bio-rational based management as treatments in controlling brinjal shoot and fruit borer of brinjal at 102 DAT (Table 8).

The highest number of healthy fruits (20.33) was recorded from $T_5$ (Spraying Success 2.5 EC @ 0.5 ml/L of water) treatment which was statistically similar with (19.00) $T_6$ (Spraying Spinosad 45% SC @ 0.01%) and closely followed (16.67, 16.00, 14.33 and 13.33) by $T_4$ (Field sanitation + Spraying Sevin 50 WP @

1.0g/L), $T_7$ (Sanitation + *Trichogramma evanescens* at the rate of 1 card/plot), $T_2$ (Braconid wasps @ 20-25/plot + sanitation) and $T_3$ (Sanitation at the 7 days interval + using Funnel Pheromone trap), respectively. Whereas the lowest number of healthy fruits (5.33) was found from $T_8$ (untreated control) treatment followed by (9.00) $T_1$ (cultural + mechanical control) treatment.

The lowest number of infested fruits was obtained from $T_5$ (2.00) treatment which was statistically similar to $T_6$ (2.33) treatment and closely followed by $T_4$ (3.33) and $T_7$ (3.67) treatment. On the other hand, the highest number of infested fruits was obtained from $T_8$ (6.67) treatment which was followed by $T_1$ (5.67) and $T_3$ (4.00) treatment and they were statistically similar.

**Table 8. Infestation of brinjal fruits caused by the brinjal shoot and fruit borer (BSFB) in different treatments at 102 DAT in number**

| Treatment | Brinjal fruit by number at 102 DAT | | | |
|---|---|---|---|---|
| | No. of Healthy fruit | No. of infested fruit | % fruit infestation | % reduction over control |
| **$T_1$** | 9.00 e | 5.67 b | 38.69 b | 30.39 |
| **$T_2$** | 14.33 cd | 3.67 c | 20.36 cd | 63.37 |
| **$T_3$** | 13.33 d | 4.00 c | 23.17 c | 58.31 |
| **$T_4$** | 16.67 bc | 3.33 c | 16.75 d | 69.86 |
| **$T_5$** | 20.33 a | 2.00 d | 8.97 e | 83.86 |
| **$T_6$** | 19.00 ab | 2.33 d | 11.01 e | 80.19 |
| **$T_7$** | 16.00 cd | 3.67 c | 18.65 d | 66.44 |
| **$T_8$** | 5.33 f | 6.67 a | 55.58 a | -- |
| **$LSD_{(0.05)}$** | 2.68 | 0.70 | 4.26 | -- |
| **CV(%)** | 10.73 | 10.24 | 10.06 | -- |

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability with 3 replications.

[$T_1$= Cultural method (clean cultivation to keep the plot free from weeds and debris to discourage pupation of insect); + mechanical control method (removal of infested roots, shoots and fruits) at the 7 days interval $T_2$= Braconid wasps at the rate of 20-25/plot at weekly interval + field sanitation; $T_3$= Sanitation at the 7 days interval + using Funnel Pheromone trap; $T_4$= Field sanitation + Spraying Sevin 50 WP @ 1.0g/ at the 7 days interval; $T_5$= Spraying Success 2.5 EC @ 0.5 ml/L of water at the 7 days interval + using Pheromone trap; $T_6$= Spraying Spinosad 45% SC @ 0.01% at 20 days interval + using Funnel Pheromone trap; $T_7$= Sanitation + *Trichogramma evanesence* at the rate of 1 card/plot at weekly interval (1000 eggs per card) $T_8$= Untreated control]

In relation to the percentage of fruit infestation, the lowest infested fruit in number was recorded from $T_5$ (8.97%) which was statistically different from that of $T_6$ (18.65%) and $T_4$ (16.75%), again the maximum infested fruits were recorded in $T_8$ (55.58%).

Infestation of fruit reduction over control (%) was estimated and the highest value was found from the treatment $T_5$ (83.86%) which was followed by $T_6$ (80.19%), $T_4$ (69.86%) and $T_7$ (66.44%) treatments and the minimum reduction of fruit infestation over control (%) from $T_1$ (30.39%) followed by $T_3$ (58.31%) treatment.

**At 109 DAT**

Number of healthy and infested fruit, infestation percentage at fruit setting stage showed statistically significant differences due to different bio-rational based management as treatments in controlling brinjal shoot and fruit borer of brinjal at 109 DAT (Table 9).

The highest number of healthy fruits (17.67) was recorded from $T_5$ (Spraying Success 2.5 EC @ 0.5 ml/L of water) treatment which was statistically similar with (17.00 and 15.33) $T_6$ (Spraying Spinosad 45% SC @ 0.01%) and $T_4$ (Field sanitation + Spraying Sevin 50 WP @ 1.0g/L), respectively and closely followed (14.67, 13.33 and 14.00) by $T_7$ (Sanitation + *Trichogramma evanesence* at the rate of 1 card/plot), $T_2$ (Braconid wasps at the rate of 20-25/plot + sanitation) and $T_3$ (Sanitation at the 7 days interval + using Funnel Pheromone trap), respectively and they were statistically similar. Whereas the lowest number of healthy fruits (4.67) was found from $T_8$ (untreated control) treatment followed by (10.00) $T_1$ (cultural + mechanical control) treatment.

The lowest number of infested fruits was obtained from $T_5$ (1.33) treatment which was statistically similar to $T_6$ (2.00) treatment and closely followed by $T_4$ (3.00) and $T_7$ (3.33) treatment. On the other hand, the highest number of infested fruits was obtained from $T_8$ (6.33) treatment which followed by $T_1$ (6.00) and $T_3$ (4.00) treatments and they were statistically similar.

In relation to the fruit infestation percentage, the lowest infested fruit in number was recorded from $T_5$ (7.03%) which was statistically different with $T_6$ (10.56%) and $T_4$ (16.40%), again the maximum infested fruits were recorded in $T_8$ (57.63%)

Infestation of fruit reduction over control (%) in number was estimated and the highest value was found from the treatment $T_5$ (87.80%) which followed by $T_6$ (81.68%), $T_4$ (71.54%) and $T_7$ (81.68%) treatments and the minimum reduction of fruit infestation over control (%) from $T_1$ (30.39%) followed by $T_3$ (61.48%) treatment (Table 9).

**Table 9. Infestation of brinjal fruits caused by the brinjal shoot and fruit borer (BSFB) in different treatments at 109 DAT in number**

| Treatment | Brinjal fruit by number at 109 DAT | | | |
|---|---|---|---|---|
| | No. of Healthy fruit | No. of infested fruit | % fruit infestation | % reduction over control |
| **$T_1$** | 10.00 d | 6.00 a | 37.53 b | 34.88 |
| **$T_2$** | 13.33 c | 3.67 bc | 21.67 c | 62.40 |
| **$T_3$** | 14.00 c | 4.00 b | 22.20 c | 61.48 |
| **$T_4$** | 15.33 abc | 3.00 c | 16.40 d | 71.54 |
| **$T_5$** | 17.67 a | 1.33 d | 7.03 f | 87.80 |
| **$T_6$** | 17.00 ab | 2.00 d | 10.56 e | 81.68 |
| **$T_7$** | 14.67 bc | 3.33 bc | 18.47 d | 67.95 |
| **$T_8$** | 4.67 e | 6.33 a | 57.63 a | -- |
| **$LSD_{(0.05)}$** | 2.46 | 0.73 | 2.96 | -- |
| **CV(%)** | 10.54 | 11.30 | 7.07 | -- |

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability with 3 replications.

[$T_1$= Cultural method (clean cultivation to keep the plot free from weeds and debris to discourage pupation of insect); + mechanical control method (removal of infested roots, shoots and fruits) at the 7 days interval $T_2$= Braconid wasps at the rate of 20-25/plot at weekly interval + field sanitation; $T_3$= Sanitation at the 7 days interval + using Funnel Pheromone trap; $T_4$= Field sanitation + Spraying Sevin 50 WP @ 1.0g/ at the 7 days interval; $T_5$= Spraying Success 2.5 EC @ 0.5 ml/L of water at the 7 days interval + using Pheromone trap; $T_6$= Spraying Spinosad 45% SC @ 0.01% at 20 days interval + using Funnel Pheromone trap; $T_7$= Sanitation + *Trichogramma evanesence* at the rate of 1 card/plot at weekly interval (1000 eggs per card) $T_8$= Untreated control]

**At 116 DAT**

Number of healthy and infested fruit, infestation percentage at fruit setting stage showed statistically significant differences due to different bio-rational based management as treatments in controlling BSFB of brinjal at 116 DAT (Table 10).

The highest number of healthy fruits (11.67) was recorded from $T_5$ (Spraying Success 2.5 EC @ 0.5 ml/L of water) treatment which was statistically similar with $T_6$ (Spraying Spinosad 45% SC @ 0.01%) (12.33) and $T_4$ (Field sanitation + Spraying Sevin 50 WP @ 1.0g/L) (11.67) and closely followed (12.33, 8.67 and 4.67) by $T_7$ (Sanitation + *Trichogramma evanesence* at the rate of 1 card/plot), $T_3$ (Sanitation at the 7 days interval + using Funnel Pheromone trap) and $T_2$ (Braconid wasps at the rate of 20-25/plot + sanitation), respectively. Whereas the lowest number of healthy fruits (14.33) was found from $T_8$ (untreated control) treatment followed by (14.67) $T_1$ (cultural + mechanical control) treatment.

The lowest number of infested fruits was obtained from $T_5$ (1.33) treatment which was statistically similar to $T_6$ (1.67) treatment and closely followed by $T_7$ (2.93) and $T_4$ (2.67) treatments. On the other hand, the highest number of infested fruits was obtained from $T_8$ (6.33) treatment which was followed by $T_1$ (5.33) and $T_3$ (3.67) treatment and they were statistically similar.

In relation to the fruit infestation percentage, the lowest infested fruit in number was recorded from $T_5$ (8.36%) which was statistically different with $T_6$ (10.43%) and $T_4$ (17.89%), again the maximum infested fruits were recorded in $T_8$ (57.63%)

Infestation of fruit reduction over control (%) was estimated and the highest value was found from the treatment $T_5$ (83.86%) which was followed by $T_6$ (81.90%), $T_4$ (68.96%) and $T_7$ (66.60%) treatments and the minimum reduction of fruit infestation over control (%) from $T_1$ (33.78%) followed by $T_3$ (58.30%) treatment.

**Table 10. Infestation of brinjal fruits caused by the brinjal shoot and fruit borer (BSFB) in different treatments at 116 DAT in number**

| Treatment | Brinjal fruit by number at 116 DAT | | | |
|---|---|---|---|---|
| | No. of Healthy fruit | No. of infested fruit | % fruit infestation | % reduction over control |
| $T_1$ | 14.67 a | 5.33 b | 38.16 b | 33.78 |
| $T_2$ | 4.67 d | 3.33 cd | 22.26 c | 61.37 |
| $T_3$ | 8.67 c | 3.67 c | 24.03 c | 58.30 |
| $T_4$ | 11.67 b | 2.67 d | 17.89 e | 68.96 |
| $T_5$ | 11.67 b | 1.33 e | 8.36 f | 85.49 |
| $T_6$ | 12.33 ab | 1.67 e | 10.43 f | 81.90 |
| $T_7$ | 12.33 ab | 2.93 d | 19.25 de | 66.60 |
| $T_8$ | 14.33 a | 6.33 a | 57.63 a | -- |
| $LSD_{(0.05)}$ | 2.42 | 0.73 | 4.37 | -- |
| CV(%) | 12.23 | 12.25 | 10.07 | -- |

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability with 3 replications.

[$T_1$= Cultural method (clean cultivation to keep the plot free from weeds and debris to discourage pupation of insect); + mechanical control method (removal of infested roots, shoots and fruits) at the 7 days interval $T_2$= Braconid wasps at the rate of 20-25/plot at weekly interval + field sanitation; $T_3$= Sanitation at the 7 days interval + using Funnel Pheromone trap; $T_4$= Field sanitation + Spraying Sevin 50 WP @ 1.0g/ at the 7 days interval; $T_5$= Spraying Success 2.5 EC @ 0.5 ml/L of water at the 7 days interval + using Pheromone trap; $T_6$= Spraying Spinosad 45% SC @ 0.01% at 20 days interval + using Funnel Pheromone trap; $T_7$= Sanitation + *Trichogramma evanesence* at the rate of 1 card/plot at weekly interval (1000 eggs per card) $T_8$= Untreated control]

### At 123 DAT

Number of healthy and infested fruit, infestation percentage at fruit setting stage showed statistically significant differences due to different bio-rational management as treatments in controlling brinjal shoot and fruit borer of brinjal at 123 DAT (Table 11).

The highest number of healthy fruits (9.67) was recorded from $T_5$ (Spraying Success 2.5 EC @ 0.5 ml/L of water) treatment which was statistically similar with $T_6$ (Spraying Spinosad 45% SC @ 0.01%) (9.33) and $T_4$ (Field sanitation + Spraying Sevin 50 WP @ 1.0g/L) (8.00) and closely followed (7.67, 7.33 and 7.00) by $T_7$ (Sanitation + *Trichogramma evanesence* at the rate of 1 card/plot), $T_2$ (Braconid wasps at the rate of 20-25/plot + sanitation), $T_3$ (Sanitation at the 7 days interval + using Funnel Pheromone trap), respectively and they were statistically similar. Whereas the lowest number of healthy fruits (2.67) was found from $T_8$ (untreated control) treatment followed by (5.00) $T_1$ (cultural + mechanical control) treatment.

The lowest number of infested fruits was obtained from $T_5$ (0.67) treatment which was statistically similar to $T_6$ (1.00) treatment and closely followed by $T_4$ (1.33) and $T_7$ (2.00) treatment. On the other hand, the highest number of infested fruits was obtained from $T_8$ (4.00) treatment which was followed by $T_1$ (3.33) and $T_3$ (2.67) treatment and they were statistically similar.

In relation to the fruit infestation percentage, the lowest infested fruit in number was recorded from $T_5$ (6.54%) which was statistically different with $T_6$ (9.80%) and $T_4$ (14.43%), again the maximum infested fruits were recorded in $T_8$ (60.04%).

**Table 11. Infestation of brinjal fruits caused by the brinjal shoot and fruit borer (BSFB) in different treatments at 123 DAT in number**

| Treatment | % Fruit infestation by number at 123 DAT | | | |
|---|---|---|---|---|
| | No. of Healthy fruit | No. of infested fruit | % fruit infestation | % reduction over control |
| $T_1$ | 5.00 d | 3.33 b | 40.03 b | 33.33 |
| $T_2$ | 7.33 c | 2.33 cd | 24.31 cd | 59.51 |
| $T_3$ | 7.00 c | 2.67 c | 27.83 c | 53.65 |
| $T_4$ | 8.00 bc | 1.33 e | 14.43 e | 75.97 |
| $T_5$ | 9.67 a | 0.67 f | 6.54 f | 89.11 |
| $T_6$ | 9.33 ab | 1.00 ef | 9.80 ef | 83.68 |
| $T_7$ | 7.67 c | 2.00 d | 20.82 d | 65.32 |
| $T_8$ | 2.67 e | 4.00 a | 60.04 a | -- |
| $LSD_{(0.05)}$ | 1.66 | 0.47 | 5.37 | -- |
| CV(%) | 13.38 | 12.45 | 12.03 | -- |

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability with 3 replications.

[$T_1$= Cultural method (clean cultivation to keep the plot free from weeds and debris to discourage pupation of insect); + mechanical control method (removal of infested roots, shoots and fruits) at the 7 days interval $T_2$= Braconid wasps at the rate of 20-25/plot at weekly interval + field sanitation; $T_3$= Sanitation at the 7 days interval + using Funnel Pheromone trap; $T_4$= Field sanitation + Spraying Sevin 50 WP @ 1.0g/ at the 7 days interval; $T_5$= Spraying Success 2.5 EC @ 0.5 ml/L of water at the 7 days interval + using Pheromone trap; $T_6$= Spraying Spinosad 45% SC @ 0.01% at 20 days interval + using Funnel Pheromone trap; $T_7$= Sanitation + *Trichogramma evanesence* at the rate of 1 card/plot at weekly interval (1000 eggs per card) $T_8$= Untreated control]

Infestation of fruit reduction over control (%) was estimated and the highest value was found from the treatment $T_5$ (89.11%) which was followed by $T_6$ (83.68%), $T_4$ (75.97%) and $T_7$ (65.32%) treatments and the minimum reduction of fruit infestation over control (%) from $T_3$ (58.30%) followed by $T_1$ (33.78%) treatment.

**At 130 DAT**

Number of healthy and infested fruit, infestation percentage at fruit setting stage showed statistically significant differences due to different bio-rational management as treatments in controlling BSFB of brinjal at 130 DAT (Table 12).

The highest number of healthy fruits (6.67) was recorded from $T_5$ (Spraying Success 2.5 EC @ 0.5 ml/L of water) treatment which was statistically similar with (6.33) $T_6$ (Spraying Spinosad 45% SC @ 0.01%) and followed by (4.67, 4.33 and 4.00) by $T_7$ (Sanitation + *Trichogramma evanesence* @ 1 card/plot), $T_2$ (Braconid wasps @ 20-25/plot + sanitation), $T_3$ (Sanitation at the 7 days interval + using Funnel Pheromone trap), respectively and they were statistically similar. Whereas the lowest number of healthy fruits (1.00) was found from $T_8$ (untreated control) treatment followed by (2.67) $T_1$ (cultural + mechanical control) treatment.

The lowest number of infested fruits was obtained from $T_5$ (0.33) treatment which was statistically similar to $T_6$ (0.67) treatment and closely followed by $T_4$ (1.00) and $T_7$ (1.33) treatment. On the other hand, the highest number of infested fruits was obtained from $T_8$ (1.67) treatment which was followed by $T_1$ (2.00) and $T_3$ (1.67) treatment and they were statistically similar.

In relation to the percentage of fruit infestation, the lowest infested fruits in number was recorded from $T_5$ (4.77%) which was statistically different with $T_6$ (9.59%) and $T_4$ (16.67%), again the maximum infested fruits were recorded in $T_8$ (62.55%)

Infestation of fruit reduction over control (%) was estimated and the highest value was found from the treatment $T_5$ (92.37%) which was followed by $T_6$ (84.67%), $T_4$ (73.35%) and $T_7$ (64.16%) treatments and the minimum reduction of fruit infestation over control (%) from $T_1$ (31.32%) followed by $T_3$ (52.71%) treatment.

**Table 12. Infestation of brinjal fruits caused by the brinjal shoot and fruit borer (BSFB) in different treatments at 130 DAT in number**

| Treatment | Brinjal fruit by number at 130 DAT | | | |
|---|---|---|---|---|
| | **No. of Healthy fruit** | **No. of infested fruit** | **% fruit infestation** | **% reduction over control** |
| **$T_1$** | 2.67 d | 2.00 a | 42.96 b | 31.32 |
| **$T_2$** | 4.33 bc | 1.25 c | 22.54 d | 63.96 |
| **$T_3$** | 4.00 c | 1.67 b | 29.58 c | 52.71 |
| **$T_4$** | 5.00 b | 1.00 d | 16.67 d | 73.35 |
| **$T_5$** | 6.67 a | 0.33 f | 4.77 e | 92.37 |
| **$T_6$** | 6.33 a | 0.67 e | 9.59 e | 84.67 |
| **$T_7$** | 4.67 bc | 1.33 c | 22.42 d | 64.16 |
| **$T_8$** | 1.00 e | 1.67 b | 62.55 a | -- |
| **$LSD_{(0.05)}$** | 0.88 | 0.24 | 6.43 | -- |
| **CV(%)** | 11.61 | 11.28 | 13.91 | -- |

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability with 3 replications.

[$T_1$= Cultural method (clean cultivation to keep the plot free from weeds and debris to discourage pupation of insect); + mechanical control method (removal of infested roots, shoots and fruits) at the 7 days interval $T_2$= Braconid wasps at the rate of 20-25/plot at weekly interval + field sanitation; $T_3$= Sanitation at the 7 days interval + using Funnel Pheromone trap; $T_4$= Field sanitation + Spraying Sevin 50 WP @ 1.0g/ at the 7 days interval; $T_5$= Spraying Success 2.5 EC @ 0.5 ml/L of water at the 7 days interval + using Pheromone trap; $T_6$= Spraying Spinosad 45% SC @ 0.01% at 20 days interval + using Funnel Pheromone trap; $T_7$= Sanitation + *Trichogramma evanesence* at the rate of 1 card/plot at weekly interval (1000 eggs per card) $T_8$= Untreated control]

## 4.4. Effect of different treatments on fruit infestation of brinjal in weight at different days after transplanting (DAT)

### At 88 DAT

Weight of healthy and infested fruit, infestation percentage at fruit setting stage showed statistically significant differences due to different bio-rational based management as treatments in controlling brinjal shoot and fruit borer of brinjal at 88 DAT (Table 13).

The highest weight of healthy fruits (1463.00 g) was recorded from $T_5$ (Spraying Success 2.5 EC @ 0.5 ml/L of water) treatment which was statistically similar with (1417.00 g) $T_6$ (Spraying Spinosad 45% SC @ 0.01%) and followed by

(1245.00 g, 1153.30 g, 1005.70 g and 867.00 g) $T_4$ (Field sanitation + Spraying Sevin 50 WP @ 1.0g/L), $T_7$ (Sanitation + *Trichogramma evanesence* at the rate of 1 card/plot), $T_2$ (Braconid wasps at the rate of 20-25/plot + sanitation), $T_3$ (Sanitation at the 7 days interval + using Funnel Pheromone trap), respectively. Whereas, the lowest weight of healthy fruits (454.30 g) was found from $T_8$ (untreated control) treatment followed by 688.00 g) $T_1$ (cultural + mechanical control) treatment.

The lowest weight of infested fruits was obtained from $T_5$ (92.00 g) treatment which was statistically similar to $T_6$ (96.00 g) treatment and closely followed by $T_4$ (129.00 g) and $T_7$ (189.33 g) treatment. On the other hand, the highest weight of infested fruit was obtained from $T_8$ (242.33 g) treatment which was followed by $T_1$ (245.33 g) and $T_3$ (237.67 g) treatment and they were statistically similar.

**Table 13. Infestation of brinjal fruits caused by the brinjal shoot and fruit borer (BSFB) in different treatments at 88 DAT in weight**

| Treatment | Brinjal fruit by weight at 88 DAT | | | |
|---|---|---|---|---|
| | Wt. of Healthy fruit (g) | Wt. of infested fruit (g) | % Infestation | % Reduction over control |
| $T_1$ | 688.0 de | 254.33 a | 27.04 b | 22.25 |
| $T_2$ | 1005.7 bc | 184.67 b | 15.51 d | 55.41 |
| $T_3$ | 867.0 cd | 237.67 a | 21.60 c | 37.90 |
| $T_4$ | 1245.0 ab | 129.00 c | 9.52 e | 72.63 |
| $T_5$ | 1463.0 a | 92.00 d | 5.93 f | 82.95 |
| $T_6$ | 1417.0 a | 96.00 cd | 6.38 f | 81.66 |
| $T_7$ | 1153.3 b | 189.33 b | 14.10 d | 59.46 |
| $T_8$ | 454.3 e | 242.33 a | 34.78 a | -- |
| $LSD_{(0.05)}$ | 240.33 | 36.37 | 3.06 | -- |
| CV(%) | 13.24 | 11.66 | 10.36 | -- |

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability with 3 replications.

[$T_1$= Cultural method (clean cultivation to keep the plot free from weeds and debris to discourage pupation of insect); + mechanical control method (removal of infested roots, shoots and fruits) at the 7 days interval $T_2$= Braconid wasps at the rate of 20-25/plot at weekly interval + field sanitation; $T_3$= Sanitation at the 7 days interval + using Funnel Pheromone trap; $T_4$= Field sanitation + Spraying Sevin 50 WP @ 1.0g/ at the 7 days interval; $T_5$= Spraying Success 2.5 EC @ 0.5 ml/L of water at the 7 days interval + using Pheromone trap; $T_6$= Spraying Spinosad 45% SC @ 0.01% at 20 days interval + using Funnel Pheromone trap; $T_7$= Sanitation + *Trichogramma evanesence* at the rate of 1 card/plot at weekly interval (1000 eggs per card) $T_8$= Untreated control]

In relation to the percentage of fruit infestation, the lowest infested fruits in weight was recorded from $T_5$ (5.93%) which was statistically different with $T_6$ (6.38%) and $T_4$ (9.52%), again the maximum infested fruits were recorded in $T_8$ (34.78%)

Infestation of fruit reduction over control (%) was estimated and the highest value was found from the treatment $T_5$ (82.95%) which was followed by $T_6$ (81.66%), $T_4$ (72.63%) and $T_7$ (59.46%) treatments and the minimum reduction of fruit infestation over control (%) from $T_1$ (22.25%) followed by $T_3$ (37.90%) treatment.

**At 95 DAT**

Weight of healthy and infested fruit, infestation percentage at fruit setting stage showed statistically significant differences due to different bio-rational based management as treatments in controlling BSFB of brinjal at 95 DAT (Table 14).

The highest weight of healthy fruits (2299.30 g) was recorded from $T_5$ (Spraying Success 2.5 EC @ 0.5 ml/L of water) treatment which was statistically similar with (2169.70 g) $T_6$ (Spraying Spinosad 45% SC @ 0.01%) and followed by (1859.70 g, 1698.00 g, 1520.00 g and 1437.70 g)) $T_4$ (Field sanitation + Spraying Sevin 50 WP @ 1.0g/L), $T_7$ (Sanitation + *Trichogramma evanesence* at the rate of 1 card/plot), $T_2$ (Braconid wasps at the rate of 20-25/plot + sanitation) and $T_3$ (Sanitation at the 7 days interval + using Funnel Pheromone trap), respectively. Wheares the lowest weight of healthy fruits (644.30 g) was found from $T_8$ (untreated control) treatment followed by (1011.00 g) $T_1$ (cultural + mechanical control) treatment.

The lowest weight of infested fruits was obtained from $T_5$ (200.67 g) treatment which was statistically similar to $T_6$ (196.67 g) treatment and closely followed by $T_4$ (303.00 g) and $T_7$ (343.00 g) treatment. On the other hand, the highest weight of infested fruit was obtained from $T_8$ (522.33 g) treatment which was followed by $T_3$ (312.00 g) and $T_1$ (428.33 g) treatment and they were statistically similar.

In relation to the fruit infestation percentage, the lowest infested fruits in weight was recorded from $T_5$ (8.11%) which was statistically different with $T_6$ (8.32%) and $T_4$ (14.05%), again the maximum infested fruits were recorded in $T_8$ (16.87%)

Infestation of fruit reduction over control (%) was estimated and the highest value was found from the treatment $T_5$ (81.89%) which was followed by $T_6$ (81.42%), $T_4$ (68.62%) and $T_7$ (62.33%) treatments and the minimum reduction of fruit infestation over control (%) from $T_3$ (60.29%) followed by $T_1$ (33.34%) treatment.

**Table 14. Infestation of brinjal fruits caused by the brinjal shoot and fruit borer (BSFB) in different treatments at 95 DAT in weight**

| Treatment | Brinjal fruit by weight at 95 DAT | | | |
|---|---|---|---|---|
| | Wt. of Healthy fruit | Wt. of infested fruit | % Infestation | % Reduction over control |
| **$T_1$** | 1011.0 e | 428.33 b | 29.85 b | 33.34 |
| **$T_2$** | 1520.0 cd | 325.67 c | 17.74 c | 60.38 |
| **$T_3$** | 1437.7 d | 312.00 c | 17.78 c | 60.29 |
| **$T_4$** | 1859.7 bc | 303.00 c | 14.05 c | 68.62 |
| **$T_5$** | 2299.3 a | 200.67 d | 8.11 d | 81.89 |
| **$T_6$** | 2169.7 ab | 196.67 d | 8.32 d | 81.42 |
| **$T_7$** | 1698.0 cd | 343.00 c | 16.87 c | 62.33 |
| **$T_8$** | 644.3 f | 522.33 a | 44.78 a | -- |
| **$LSD_{(0.05)}$** | 352.60 | 78.30 | 4.01 | -- |
| **CV(%)** | 12.74 | 13.59 | 11.64 | -- |

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability with 3 replications.

[$T_1$= Cultural method (clean cultivation to keep the plot free from weeds and debris to discourage pupation of insect); + mechanical control method (removal of infested roots, shoots and fruits) at the 7 days interval $T_2$= Braconid wasps at the rate of 20-25/plot at weekly interval + field sanitation; $T_3$= Sanitation at the 7 days interval + using Funnel Pheromone trap; $T_4$= Field sanitation + Spraying Sevin 50 WP @ 1.0g/ at the 7 days interval; $T_5$= Spraying Success 2.5 EC @ 0.5 ml/L of water at the 7 days interval + using Pheromone trap; $T_6$= Spraying Spinosad 45% SC @ 0.01% at 20 days interval + using Funnel Pheromone trap; $T_7$= Sanitation + *Trichogramma evanesence* at the rate of 1 card/plot at weekly interval (1000 eggs per card) $T_8$= Untreated control]

### At 102 DAT

Weight of healthy and infested fruit, infestation percentage at fruit setting stage showed statistically significant differences due to different bio-rational based management as treatments in controlling brinjal shoot and fruit borer of brinjal at 102 DAT (Table 15).

The highest weight of healthy fruits (3558.00 g) was recorded from $T_5$ (Spraying Success 2.5 EC @ 0.5 ml/L of water) treatment which was statistically similar with (3263.70 g) $T_6$ (Spraying Spinosad 45% SC @ 0.01%) and followed by

(2703.70 g, 2471.30 g, 2207.30 g and 2007.70 g) $T_4$ (Field sanitation + Spraying Sevin 50 WP @ 1.0 g/L), $T_7$ (Sanitation + *Trichogramma evanesence* at the rate of 1 card/plot), $T_2$ (Braconid wasps at the rate of 20-25/plot + sanitation) and $T_3$ (Sanitation at the 7 days interval + using Funnel Pheromone trap), respectively. Whereas the lowest weight of healthy fruits (738.00 g) was found from $T_8$ (untreated control) treatment followed by (1395.70 g) $T_1$ (cultural + mechanical control) treatment.

The lowest weight of infested fruits was obtained from $T_5$ (308.67 g) treatment which was statistically similar to $T_6$ (352.67 g) treatment and closely followed by $T_4$ (475.67 g) and $T_7$ (513.00 g) treatment. On the other hand, the highest weight of infested fruit was obtained from $T_8$ (828.67 g) treatment which was followed by $T_1$ (710.33 g) and $T_3$ (499.33 g) treatment and they were statistically significant.

**Table 15. Infestation of brinjal fruits caused by the brinjal shoot and fruit borer (BSFB) in different treatments at 102 DAT in weight**

| Treatment | Brinjal fruit by weight at 102 DAT | | | |
|---|---|---|---|---|
| | Wt. of Healthy fruit | Wt. of infested fruit | % Infestation | % Reduction over control |
| $T_1$ | 1395.7 e | 710.33 b | 33.75 b | 36.20 |
| $T_2$ | 2207.3 cd | 471.67 c | 17.63 cd | 66.67 |
| $T_3$ | 2007.7 d | 499.33 c | 20.02 c | 62.16 |
| $T_4$ | 2703.7 b | 475.67 c | 14.96 d | 71.72 |
| $T_5$ | 3558.0 a | 308.67 d | 8.00 e | 84.88 |
| $T_6$ | 3263.7 a | 352.67 d | 9.77 e | 81.53 |
| $T_7$ | 2471.3 bc | 513.00 c | 17.19 cd | 67.50 |
| $T_8$ | 738.0 f | 828.67 a | 52.90 a | -- |
| $LSD_{(0.05)}$ | 444.55 | 106.57 | 2.88 | -- |
| CV(%) | 11.07 | 11.70 | 7.54 | -- |

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability with 3 replications.

[$T_1$= Cultural method (clean cultivation to keep the plot free from weeds and debris to discourage pupation of insect); + mechanical control method (removal of infested roots, shoots and fruits) at the 7 days interval $T_2$= Braconid wasps at the rate of 20-25/plot at weekly interval + field sanitation; $T_3$= Sanitation at the 7 days interval + using Funnel Pheromone trap; $T_4$= Field sanitation + Spraying Sevin 50 WP @ 1.0g/ at the 7 days interval; $T_5$= Spraying Success 2.5 EC @ 0.5 ml/L of water at the 7 days interval + using Pheromone trap; $T_6$= Spraying Spinosad 45% SC @ 0.01% at 20 days interval + using Funnel Pheromone trap; $T_7$= Sanitation + *Trichogramma evanesence* at the rate of 1 card/plot at weekly interval (1000 eggs per card) $T_8$= Untreated control]

In relation to the percentage of fruit infestation, the lowest infested fruits in weight was recorded from $T_5$ (8.00%) which was statistically different with $T_6$ (9.77%) and $T_4$ (14.96%), again the maximum infested fruits were recorded in $T_8$ (52.90%)

Infestation of fruit reduction over control (%) in weight was estimated and the highest value was found from the treatment $T_5$ (84.88%) which was followed by $T_6$ (81.53%), $T_4$ (71.72%) and $T_7$ (67.50%) treatments and the minimum reduction of fruit infestation over control (%) from $T_3$ (62.16%) followed by $T_1$ (36.20%) treatment.

**At 109 DAT**

Weight of healthy and infested fruit, infestation percentage at fruit setting stage showed statistically significant differences due to different bio-rational management as treatments in controlling brinjal shoot and fruit borer of brinjal (Table 16) at 109 DAT.

The highest weight of healthy fruits (3120.00 g) was recorded from $T_5$ (Spraying Success 2.5 EC @ 0.5 ml/L of water) treatment which was statistically similar with (2756.70 g) $T_6$ (Spraying Spinosad 45% SC @ 0.01%) and followed by (2386.30 g, 2276.30 g, 2001.30 g and 1918.00 g) $T_4$ (Field sanitation + Spraying Sevin 50 WP @ 1.0 g/L), $T_7$ (Sanitation + *Trichogramma evanesence* at the rate of 1 card/plot), $T_2$ (Braconid wasps @ 20-25/plot + sanitation) and $T_3$ (Sanitation at the 7 days interval + using Funnel Pheromone trap), respectively. Whereas the lowest weight of healthy fruits (642.30 g) was found from $T_8$ (untreated control) treatment followed by (1379.30 g) $T_1$ (cultural + mechanical control) treatment.

The lowest weight of infested fruits was obtained from $T_5$ (198.67 g) treatment which was statistically similar to $T_6$ (301.67 g) treatment and closely followed by $T_4$ (402.33 g) and $T_7$ (451.67 g) treatment. On the other hand, the highest weight of infested fruit was obtained from $T_8$ (694.33 g) treatment which was followed by $T_1$ (687.33 g) and $T_3$ (495.67 g) treatment and they were statistically significant.

In relation to the fruit infestation percentage, the lowest infested fruits in weight was recorded from $T_5$ (5.99%) which was statistically different with $T_6$ (9.94%) and $T_4$ (14.44%), again the maximum infested fruits were recorded in $T_8$ (52.02%).

Infestation of fruit reduction over control (%) was estimated and the highest value was found from the treatment $T_5$ (88.49%) which was followed by $T_6$ (80.89%), $T_4$ (72.24%) and $T_7$ (68.11%) treatments and the minimum reduction of fruit infestation over control (%) from $T_1$ (36.24%) followed by $T_3$ (60.50%) treatment.

**Table 16. Infestation of brinjal fruits caused by the brinjal shoot and fruit borer (BSFB) in different treatments at 109 DAT in weight**

| Treatment | % Fruit infestation by weight at 109 DAT | | | |
|---|---|---|---|---|
| | Wt. of Healthy fruit | Wt. of infested fruit | % Infestation | % Reduction over control |
| $T_1$ | 1379.30 e | 687.33 a | 33.17 b | 36.24 |
| $T_2$ | 2001.30 cd | 471.67 b | 19.12 cd | 63.24 |
| $T_3$ | 1918.00 d | 495.67 b | 20.55 c | 60.50 |
| $T_4$ | 2386.30 bc | 402.33 bc | 14.44 e | 72.24 |
| $T_5$ | 3120.00 a | 198.67 d | 5.99 g | 88.49 |
| $T_6$ | 2756.70 ab | 301.67 cd | 9.94 f | 80.89 |
| $T_7$ | 2276.30 cd | 451.67 b | 16.59 de | 68.11 |
| $T_8$ | 642.30 f | 694.33 a | 52.02 a | -- |
| $LSD_{(0.05)}$ | 391.22 | 112.02 | 3.21 | -- |
| CV(%) | 10.84 | 13.82 | 8.53 | -- |

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability with 3 replications.

[$T_1$= Cultural method (clean cultivation to keep the plot free from weeds and debris to discourage pupation of insect); + mechanical control method (removal of infested roots, shoots and fruits) at the 7 days interval $T_2$= Braconid wasps at the rate of 20-25/plot at weekly interval + field sanitation; $T_3$= Sanitation at the 7 days interval + using Funnel Pheromone trap; $T_4$= Field sanitation + Spraying Sevin 50 WP @ 1.0g/ at the 7 days interval; $T_5$= Spraying Success 2.5 EC @ 0.5 ml/L of water at the 7 days interval + using Pheromone trap; $T_6$= Spraying Spinosad 45% SC @ 0.01% at 20 days interval + using Funnel Pheromone trap; $T_7$= Sanitation + *Trichogramma evanesence* at the rate of 1 card/plot at weekly interval (1000 eggs per card) $T_8$= Untreated control]

## At 116 DAT

Weight of healthy and infested fruit, infestation percentage at fruit setting stage showed statistically significant differences due to different bio-rational based management as treatments in controlling brinjal shoot and fruit borer of brinjal at 116 DAT (Table 17).

The highest weight of healthy fruits (2578.30 g) was recorded from $T_5$ (Spraying Success 2.5 EC @ 0.5 ml/L of water) treatment which was statistically similar with (2458.30 g) $T_6$ (Spraying Spinosad 45% SC @ 0.01%) and followed by (1987.00 g, 1904.30 g, 1757.30 g and 1676.70 g) $T_4$ (Field sanitation + Spraying Sevin 50 WP @ 1.0g/L), $T_7$ (Sanitation + *Trichogramma evanesence* @ 1 card/plot), $T_2$ (Braconid wasps @ 20-25/plot + sanitation) and $T_3$ (Sanitation at the 7 days interval + using Funnel Pheromone trap), respectively. Whereas the lowest weight of healthy fruits (636.30 g) was found from $T_8$ (untreated control) treatment followed by (1204.30 g) $T_1$ (cultural + mechanical control) treatment.

The lowest weight of infested fruits was obtained from $T_5$ (199.33 g) treatment which was statistically similar to $T_6$ (243.00 g) treatment and closely followed by $T_4$ (363.00 g) and $T_7$ (395.67 g) treatment. On the other hand, the highest weight of infested fruit was obtained from $T_8$ (650.33 g) treatment which was followed by $T_1$ (582.33 g) and $T_3$ (438.00 g) treatment and they were statistically significant.

In relation to the percentage of fruit infestation, the lowest infested fruits in weight was recorded from $T_5$ (7.20%) which was statistically different with $T_6$ (9.00%) and $T_4$ (15.44%), again the maximum infested fruits were recorded in $T_8$ (50.60%).

Infestation of fruit reduction over control (%) was estimated and the highest value was found from the treatment $T_5$ (85.77%) which was followed by $T_6$ (82.21%), $T_4$ (69.49%) and $T_7$ (65.87%) treatments and the minimum reduction of fruit infestation over control (%) from $T_3$ (59.11%) followed by $T_1$ (35.69%) treatment (Table 17).

**Table 17. Infestation of brinjal fruits caused by the brinjal shoot and fruit borer (BSFB) in different treatments at 116 DAT in weight**

| Treatment | Brinjal fruit by weight at 116 DAT | | | |
|---|---|---|---|---|
| | Wt. of Healthy fruit | Wt. of infested fruit | % Infestation | % Reduction over control |
| $T_1$ | 1204.3 c | 582.33 a | 32.54 b | 35.69 |
| $T_2$ | 1757.3 b | 412.67 b | 19.01 cd | 62.43 |
| $T_3$ | 1676.7 b | 438.00 b | 20.69 c | 59.11 |
| $T_4$ | 1987.0 b | 363.00 b | 15.44 e | 69.49 |
| $T_5$ | 2578.3 a | 199.33 c | 7.20 f | 85.77 |
| $T_6$ | 2458.3 a | 243.00 c | 9.00 f | 82.21 |
| $T_7$ | 1904.3 b | 395.67 b | 17.27 de | 65.87 |
| $T_8$ | 636.3 d | 650.33 a | 50.60 a | -- |
| $LSD_{(0.05)}$ | 384.58 | 101.54 | 3.07 | -- |
| CV(%) | 12.37 | 14.12 | 8.17 | -- |

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability with 3 replications.

[$T_1$= Cultural method (clean cultivation to keep the plot free from weeds and debris to discourage pupation of insect); + mechanical control method (removal of infested roots, shoots and fruits) at the 7 days interval $T_2$= Braconid wasps at the rate of 20-25/plot at weekly interval + field sanitation; $T_3$= Sanitation at the 7 days interval + using Funnel Pheromone trap; $T_4$= Field sanitation + Spraying Sevin 50 WP @ 1.0g/ at the 7 days interval; $T_5$= Spraying Success 2.5 EC @ 0.5 ml/L of water at the 7 days interval + using Pheromone trap; $T_6$= Spraying Spinosad 45% SC @ 0.01% at 20 days interval + using Funnel Pheromone trap; $T_7$= Sanitation + *Trichogramma evanesence* at the rate of 1 card/plot at weekly interval (1000 eggs per card) $T_8$= Untreated control]

### At 123 DAT

Weight of healthy and infested fruit, infestation percentage at fruit setting stage showed statistically significant differences due to different bio-rational management as treatments in controlling BSFB of brinjal at 123 DAT (Table 18).

The highest weight of healthy fruits (1673.00 g) was recorded from $T_5$ (Spraying Success 2.5 EC @ 0.5 ml/L of water) treatment which was statistically similar with (1588.30 g) $T_6$ (Spraying Spinosad 45% SC @ 0.01%) followed by (1277.30 g, 1171.30 g, 1073.30 g and 1002.70 g) $T_4$ (Field sanitation + Spraying Sevin 50 WP @ 1.0g/L), $T_7$ (Sanitation + *Trichogramma evanesence* at the rate of 1 card/plot), $T_2$ (Braconid wasps at the rate of 20-25/plot + sanitation) and $T_3$ (Sanitation at the 7 days interval + using Funnel Pheromone trap), respectively. Whereas, the lowest weight of healthy fruits (350.30 g) was found from $T_8$

(untreated control) treatment followed by (690.7 g) $T_1$ (cultural + mechanical control method) treatment.

The lowest weight of infested fruits was obtained from $T_5$ (97.67 g) treatment which was statistically similar to $T_6$ (147.00 g) treatment and closely followed by $T_4$ (183.67 g) and $T_7$ (255.67 g) treatment. On the other hand, the highest weight of infested fruit was obtained from $T_8$ (403.00 g) treatment which was followed by $T_1$ (366.67 g) and $T_3$ (322.67 g) treatment and they were statistically significant.

In relation to the fruit infestation percentage, the lowest infested fruits in weight was recorded from $T_5$ (5.51%) which was statistically different with $T_6$ (8.48%) and $T_4$ (12.66%), again the maximum infested fruits were recorded in $T_8$ (53.50%).

**Table 18. Infestation of brinjal fruits caused by the brinjal shoot and fruit borer (BSFB) in different treatments at 123 DAT in weight**

| Treatment | Brinjal fruit by weight at 123 DAT | | | |
|---|---|---|---|---|
| | Wt. of Healthy fruit | Wt. of infested fruit | % Infestation | % Reduction over control |
| $T_1$ | 690.7 d | 366.67 ab | 34.78 b | 34.99 |
| $T_2$ | 1073.3 bc | 288.67 cd | 21.25 cd | 60.28 |
| $T_3$ | 1002.7 c | 322.67 bc | 24.31 c | 54.56 |
| $T_4$ | 1277.3 b | 183.67 e | 12.66 e | 76.34 |
| $T_5$ | 1673.0 a | 97.67 f | 5.51 f | 89.70 |
| $T_6$ | 1588.3 a | 147.00 ef | 8.48 ef | 84.15 |
| $T_7$ | 1171.3 bc | 255.67 d | 18.03 d | 66.30 |
| $T_8$ | 350.3 e | 403.00 a | 53.50 a | -- |
| $LSD_{(0.05)}$ | 211.11 | 59.52 | 5.23 | -- |
| CV(%) | 10.93 | 13.17 | 13.38 | -- |

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability with 3 replications.

[$T_1$= Cultural method (clean cultivation to keep the plot free from weeds and debris to discourage pupation of insect); + mechanical control method (removal of infested roots, shoots and fruits) at the 7 days interval $T_2$= Braconid wasps at the rate of 20-25/plot at weekly interval + field sanitation; $T_3$= Sanitation at the 7 days interval + using Funnel Pheromone trap; $T_4$= Field sanitation + Spraying Sevin 50 WP @ 1.0g/ at the 7 days interval; $T_5$= Spraying Success 2.5 EC @ 0.5 ml/L of water at the 7 days interval + using Pheromone trap; $T_6$= Spraying Spinosad 45% SC @ 0.01% at 20 days interval + using Funnel Pheromone trap; $T_7$= Sanitation + *Trichogramma evanesence* at the rate of 1 card/plot at weekly interval (1000 eggs per card) $T_8$= Untreated control]

Infestation of fruit reduction over control (%) was estimated and the highest value was found from the treatment $T_5$ (89.70%) which was followed by $T_6$ (84.15%), $T_4$

(76.34%) and $T_7$ (66.30%) treatments and the minimum reduction of fruit infestation over control (%) from $T_1$ (34.99%) followed by $T_3$ (54.56%) treatment.

Mohanty *et al.* (2000) also showed that parasitoids had positive efficiency against BSFB and reported that fruit damage (0.1-5.1%) was reduced in the parasitoid released field compared to the control.

**At 130 DAT**

Weight of healthy and infested fruit, infestation percentage at fruit setting stage showed statistically significant differences due to different bio-rational based management as treatments in controlling brinjal shoot and fruit borer of brinjal at 130 DAT (Table 19).

The highest weight of healthy fruits (1159.30 g) was recorded from $T_5$ (Spraying Success 2.5 EC @ 0.5 ml/L of water) treatment which was statistically similar with (1079.70 g) $T_6$ (Spraying Spinosad 45% SC @ 0.01%) and followed by (793.00 g, 722.30 g, 666.30 g and 597.70 g) $T_4$ (Field sanitation + Spraying Sevin 50 WP @ 1.0g/L), $T_7$ (Sanitation + *Trichogramma evanesence* at the rate of 1 card/plot), $T_2$ (Braconid wasps @ 20-25/plot + sanitation) and $T_3$ (Sanitation at the 7 days interval + using Funnel Pheromone trap), respectively. Whereas the lowest weight of healthy fruits (118.30g) was found from $T_8$ (untreated control) treatment followed by (345.30 g) $T_1$ (Cultural + mechanical control method) treatment.

The lowest weight of infested fruits was obtained from $T_5$ (45.67 g) treatment which was statistically similar to $T_6$ (94.33 g) treatment and closely followed by $T_4$ (133.67 g) and $T_7$ (170.00 g) treatment. On the other hand, the highest weight of infested fruit was obtained from $T_8$ (172.00 g) treatment which was followed by $T_3$ (199.33 g) and $T_1$ (215.00 g) treatment and they were statistically significant.

In relation to the fruit infestation percentage, the lowest infested fruits in weight was recorded from $T_5$ (3.81%) which was statistically different with $T_6$ (8.18%) and $T_4$ (14.38%), again the maximum infested fruits were recorded in $T_8$ (59.22%).

Infestation of fruit reduction over control (%) was estimated and the highest value was found from the treatment $T_5$ (93.57%) which was followed by $T_6$ (86.19%), $T_4$

(75.72%) and $T_7$ (67.49%) treatments and the minimum reduction of fruit infestation over control (%) from $T_3$ (57.46%) followed by $T_1$ (34.95%) treatment.

Dutta *et al*. (2011) reported similar type of result that the use of pheromone trap starting from 15 days after transplanting till final harvest gave substantial protection in shoot damage (58.39%), fruit damage (38.17%).

**Table 19. Infestation of brinjal fruits caused by the brinjal shoot and fruit borer (BSFB) in different treatments at 130 DAT in weight**

| Treatment | Brinjal fruit by weight at 130 DAT | | | |
|---|---|---|---|---|
| | Wt. of Healthy fruit | Wt. of infested fruit | % Infestation | % Reduction over control |
| $T_1$ | 345.3 d | 215.00 a | 38.52 b | 34.95 |
| $T_2$ | 666.3 bc | 165.33 bc | 20.07 cd | 66.11 |
| $T_3$ | 597.7 c | 199.00 ab | 25.19 c | 57.46 |
| $T_4$ | 793.0 b | 133.67 c | 14.38 d | 75.72 |
| $T_5$ | 1159.3 a | 45.67 e | 3.81 e | 93.57 |
| $T_6$ | 1079.7 a | 94.33 d | 8.18 e | 86.19 |
| $T_7$ | 722.3 bc | 170.00 b | 19.25 d | 67.49 |
| $T_8$ | 118.3 e | 172.00 b | 59.22 a | -- |
| $LSD_{(0.05)}$ | 176.98 | 35.95 | 5.78 | -- |
| CV(%) | 14.75 | 13.74 | 14.00 | -- |

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability with 3 replications

[$T_1$= Cultural method (clean cultivation to keep the plot free from weeds and debris to discourage pupation of insect); + mechanical control method (removal of infested roots, shoots and fruits) at the 7 days interval $T_2$= Braconid wasps at the rate of 20-25/plot at weekly interval + field sanitation; $T_3$= Sanitation at the 7 days interval + using Funnel Pheromone trap; $T_4$= Field sanitation + Spraying Sevin 50 WP @ 1.0g/ at the 7 days interval; $T_5$= Spraying Success 2.5 EC @ 0.5 ml/L of water at the 7 days interval + using Pheromone trap; $T_6$= Spraying Spinosad 45% SC @ 0.01% at 20 days interval + using Funnel Pheromone trap; $T_7$= Sanitation + *Trichogramma evanesence* at the rate of 1 card/plot at weekly interval (1000 eggs per card) $T_8$= Untreated control]

## 4.5. Effect of Different Treatments on Growth Parameter and Weight of Individual Fruit in Brinjal at different days after transplanting (DAT)

### At 88 DAT

### Individual fruit weight (g)

The highest weight of individual fruit weight (170.00 g) was obtained in $T_5$ treatment which was statistically similar (167.13 g and 161.67 g) with $T_6$ and $T_4$

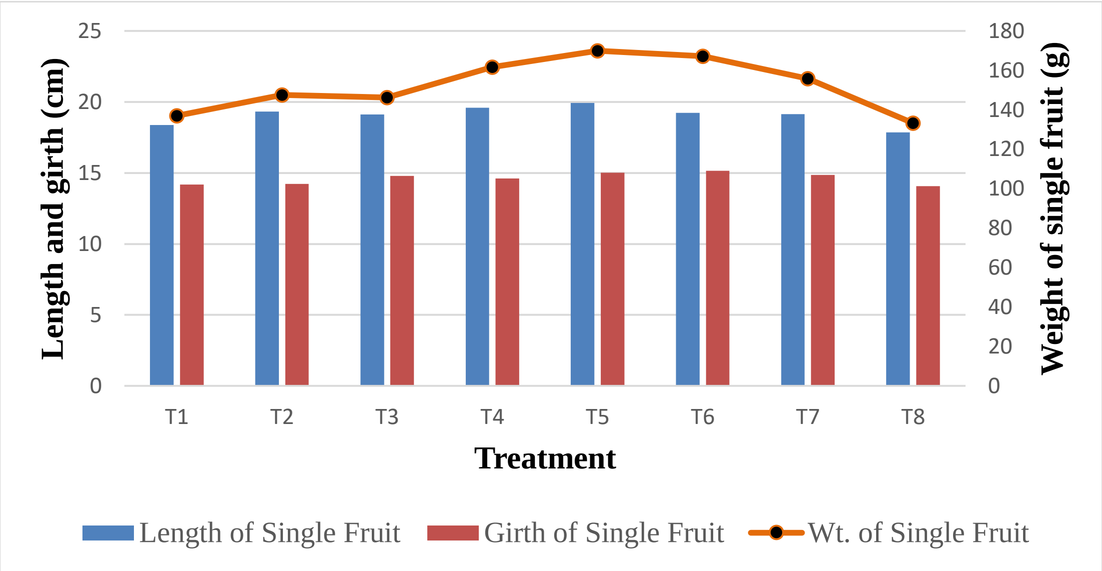
treatment, respectively. On the other hand, the lowest weight (133.23 g) was recorded in $T_8$ treatment which was statistically similar (137.00 g) with $T_1$ (Figure 6).

### Length of individual fruit (cm)

The maximum length of healthy fruit (19.93 cm) was found from $T_5$ treatment which was closely followed by $T_4$ (19.59), $T_2$ (19.32) and $T_6$ (19.24) treatment, whereas the minimum length (17.86 cm) was found in $T_8$ treatment followed by $T_1$ (18.38) and $T_7$ treatment (19.15) (Figure 6).

### Girth of individual fruit (cm)

In case of girth of fruit at 88 DAT, there were no significant differences among the treatments. The maximum girth of healthy fruit (15.16 cm) was found in $T_6$ treatment which was numerically different from $T_5$ (15.01 cm), $T_7$ (14.85 cm), $T_3$ (14.80 cm) and $T_4$ (14.61 cm). On the other hand, the minimum girth of healthy fruit (14.07 cm) was recorded in $T_8$ treatment. (Figure 6).




[$T_1$= Cultural method (clean cultivation to keep the plot free from weeds and debris to discourage pupation of insect); + mechanical control method (removal of infested roots, shoots and fruits) at the 7 days interval $T_2$= Braconid wasps at the rate of 20-25/plot at weekly interval + field sanitation; $T_3$= Sanitation at the 7 days interval + using Funnel Pheromone trap; $T_4$= Field sanitation + Spraying Sevin 50 WP @ 1.0g/ at the 7 days interval; $T_5$= Spraying Success 2.5 EC @ 0.5 ml/L of water at the 7 days interval + using Pheromone trap; $T_6$= Spraying Spinosad 45% SC @ 0.01% at 20 days interval + using Funnel Pheromone trap; $T_7$= Sanitation + *Trichogramma evanesence* at the rate of 1 card/plot at weekly interval (1000 eggs per card) $T_8$= Untreated control]

**Figure 6:** Effect of different treatments against brinjal shoot and fruit borer (BSFB) in terms of length, girth and weight of single fruit at 88 DAT

**Single Fruit at 95 DAT**

**Individual fruit weight (g)**

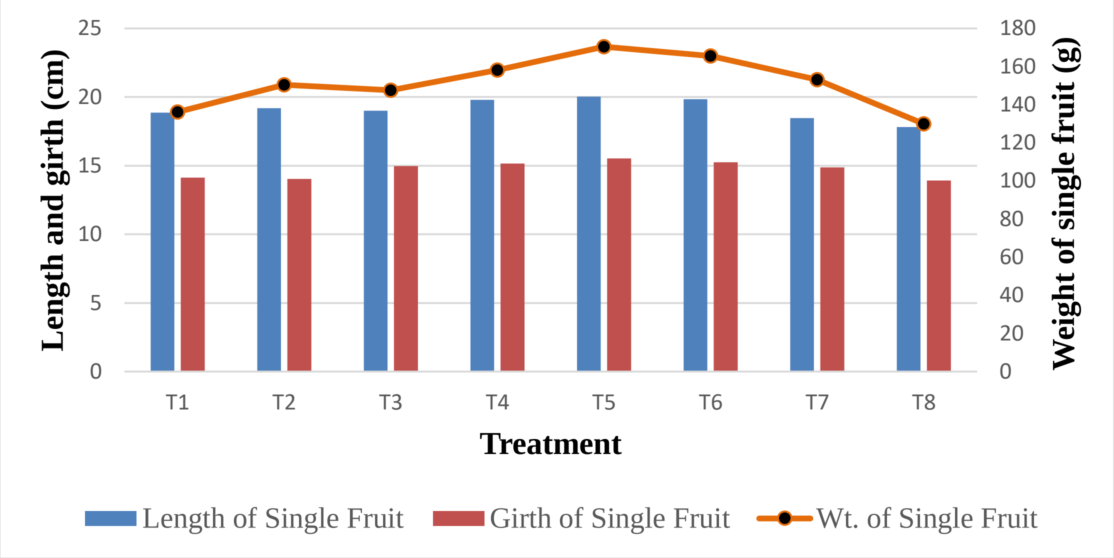
From figure 7, it was observed that the highest weight of individual fruit weight (170.40 g) was obtained from $T_5$ treatment followed (165.47 g, 158.13 g, 153.07 g, 150.47 g and 147.53 g, respectively) by $T_6$, $T_4$, $T_7$, $T_2$ and $T_3$ treatment. On the other hand, the lowest weight (129.87 g) was recorded from $T_8$ treatment which was followed (136.13 g) by $T_1$ treatment.

**Length of individual fruit (cm)**

The maximum length of healthy fruit (20.02 cm) was found from $T_5$ treatment which was statistically similar with (19.85, 19.79, 19.18, and 19.01 cm, respectively) to $T_6$, $T_4$, $T_2$ and $T_3$ treatment, whereas the minimum length (16.20 cm) was found in $T_8$ treatment followed (18.47 cm and 18.85 cm, respectively) by $T_7$ and $T_1$ treatment (Figure 7).

**Girth of individual fruit (cm)**

The maximum girth of healthy fruit (15.53 cm) was found in $T_5$ treatment which was non-significant from rest of the treatments but numerically different from $T_6$, (15.24 cm), $T_4$ (15.15 cm), $T_3$ (14.97 cm) and $T_7$ (14.88 cm). On the other hand, the minimum girth of healthy fruit (13.93 cm) was recorded in $T_8$ treatment which followed (14.03 cm and 14.14 cm, respectively) by $T_2$ and $T_1$ treatment (Figure 7).




[$T_1$= Cultural method + mechanical control; $T_2$= Braconid wasps @ 20-25/plot + Sanitation; $T_3$= Sanitation + Funnel Pheromone trap; $T_4$= Sanitation + Sevin 50 WP @ 1.0g/L; $T_5$= Success 2.5 EC @ 0.5 ml/L of water + Pheromone trap; $T_6$= Spinosad 45% SC @ 0.01% + Funnel Pheromone trap; $T_7$= Sanitation + *Trichogramma evanesence* @ 1 card/plot (1000 eggs per card) $T_8$= Untreated control]

**Figure 7:** Effect of different treatments against brinjal shoot and fruit borer (BSFB) in terms of length, girth and weight of single fruit at 95 DAT

**Single Fruit at 102 DAT**

**Individual fruit weight (g)**

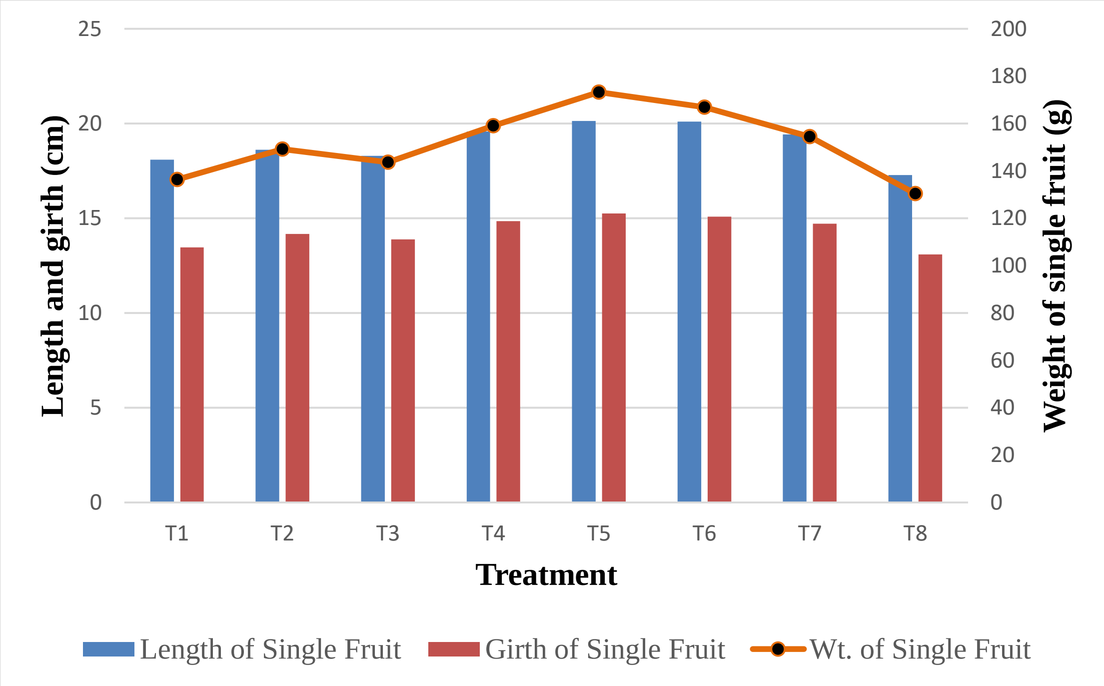
From Figure 8, it was observed that the highest weight of individual fruit weight (173.34 g) was obtained from $T_5$ treatment which was statistically similar with rest of the treatment except $T_1$ (136.45 g) and $T_8$ (130.45 g) treatment. On the other hand, the lowest weight (130.45 g) was recorded from $T_8$ treatment followed (136.45 g, 143.67 g, 149.22 g, and 154.56 g, respectively) by $T_1$, $T_3$, $T_2$ and $T_7$ treatment.

**Length of individual fruit (cm)**

The maximum length of healthy fruit (20.14 cm) was found from $T_5$ treatment followed (20.10 cm, 19.59 cm, 19.43 cm, 18.62 cm and 18.29 cm, respectively) by $T_6$, $T_4$, $T_7$, $T_2$ and $T_3$ treatment, whereas the minimum length (16.20 cm) was found in $T_8$ treatment which was statistically different from $T_5$ and $T_6$ treatment and numerically different from rest of the treatment (Figure 8).

**Girth of individual fruit (cm)**

In case of girth of brinjal fruit, there was no significant difference among the treatments. The maximum girth of healthy fruit (15.25 cm) was recorded from $T_5$ treatment which was numerically different from $T_6$ (15.08 cm), $T_4$ (14.85 cm), $T_7$ (14.71 cm), and $T_2$ (14.17 cm) treatment, whereas, the minimum girth of healthy fruit (13.10 cm) was recorded from $T_8$ treatment followed (13.46 cm) by $T_1$ treatment (Figure 8).




[$T_1$= Cultural method + mechanical control; $T_2$= Braconid wasps @ 20-25/plot + Sanitation; $T_3$= Sanitation + Funnel Pheromone trap; $T_4$= Sanitation + Sevin 50 WP @ 1.0g/L; $T_5$= Success 2.5 EC @ 0.5 ml/L of water + Pheromone trap; $T_6$= Spinosad 45% SC @ 0.01% + Funnel Pheromone trap; $T_7$= Sanitation + *Trichogramma evanesence* @ 1 card/plot (1000 eggs per card) $T_8$= Untreated control]

**Figure 8:** Effect of different treatments against brinjal shoot and fruit borer (BSFB) in terms of length, girth and weight of single fruit at 102 DAT

**Single Fruit at 109 DAT**

**Individual fruit weight**

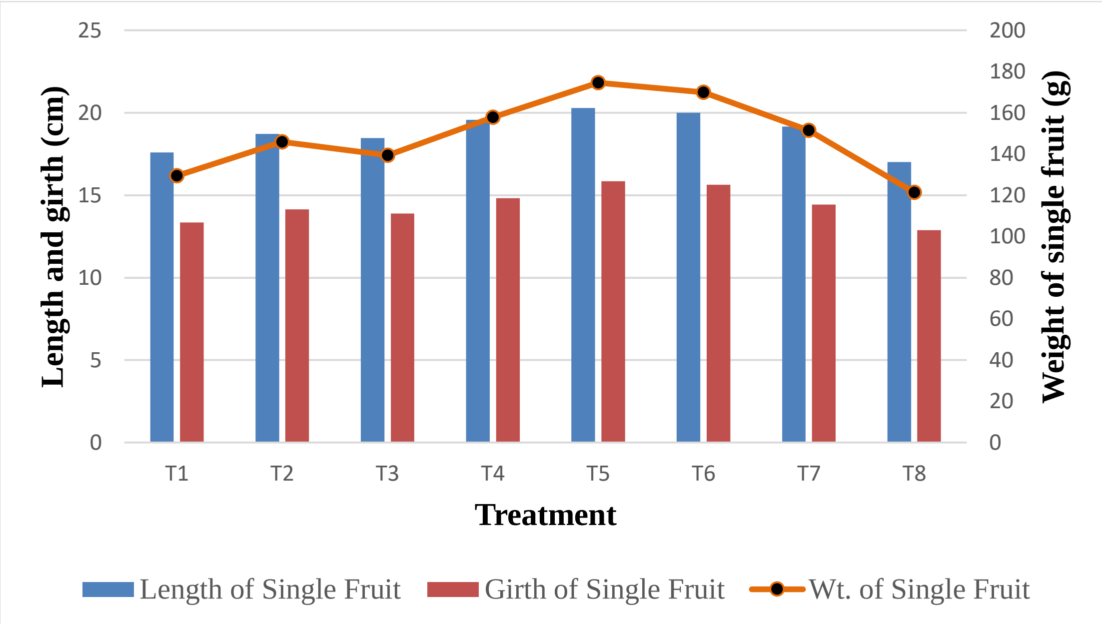
From figure 9, it was observed that at 109 DAT the highest weight of individual fruit weight (174.56 g) was recorded from $T_5$ treatment which was statistically different from rest of the treatment except $T_6$ (170.0 g), $T_4$ (157.78 g), $T_7$ (151.44 g) and $T_2$ (145.89 g) treatment. On the other hand, the lowest weight (121.32 g) was recorded from $T_8$ treatment.

### Length of individual fruit (cm)

The maximum length of healthy fruit (20.29 cm) was found from $T_5$ treatment followed (20.0 cm, 19.57 cm, 19.17 cm, 18.73 cm and 18.48 cm, respectively) by $T_6$, $T_4$, $T_7$, $T_2$ and $T_3$ treatment, whereas the minimum length (15.90 cm) was found when plot remained untreated ($T_8$) and followed (17.59 cm) by $T_1$ treatment (Figure 9).

### Girth of individual fruit (cm)

In case of girth of brinjal fruit, there was no significant differences among the treatments. The maximum girth of healthy fruit (15.85 cm) was recorded from $T_5$ treatment which was numerically different from $T_6$ (15.64), $T_4$ (14.83), $T_7$ (14.43), $T_2$ (14.14), and $T_3$ (13.89) treatment, whereas, the minimum girth of healthy fruit (12.88 cm) was recorded from $T_8$ treatment followed 13.34 cm by $T_1$ treatment (Figure 9).




[$T_1$= Cultural method + mechanical control; $T_2$= Braconid wasps @ 20-25/plot + Sanitation; $T_3$= Sanitation + Funnel Pheromone trap; $T_4$= Sanitation + Sevin 50 WP @ 1.0g/L; $T_5$= Success 2.5 EC @ 0.5 ml/L of water + Pheromone trap; $T_6$= Spinosad 45% SC @ 0.01% + Funnel Pheromone trap; $T_7$= Sanitation + *Trichogramma evanesence* @ 1 card/plot (1000 eggs per card) $T_8$= Untreated control]

**Figure 9:** Effect of different treatments against brinjal shoot and fruit borer (BSFB) in terms of length, girth and weight of single fruit at 109 DAT.

**Single fruit at 116 DAT**

**Weight of single fruit (g)**

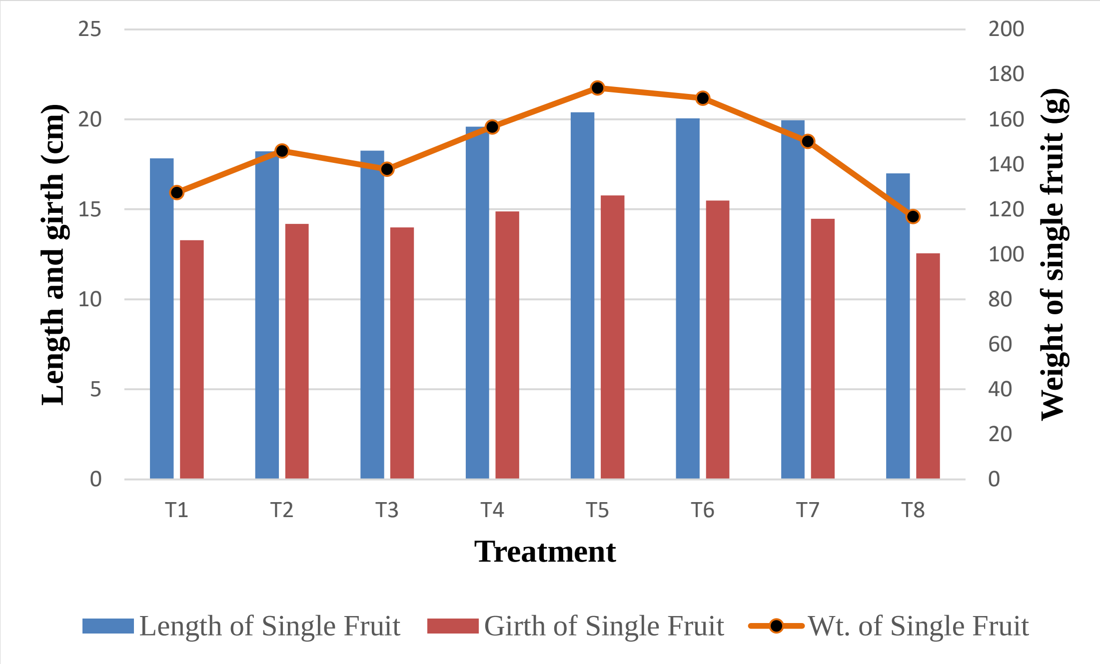
From Figure 10, it was observed that at 116 DAT the highest weight of individual fruit weight (174.0 g) was recorded from $T_5$ treatment which was statistically different from rest of the treatment except $T_6$ (169.33 g), $T_4$ (156.67 g), $T_7$ (150.22 g) and $T_2$ (146.0 g) treatment. On the other hand, the lowest weight (116.78 g) was recorded from $T_8$ treatment which was similar with (127.44 g and 137.89 g, respectively) to $T_1$ and $T_3$ treatment.

**Length of individual fruit (cm)**

The maximum length of healthy fruit (20.39 cm) was found from $T_5$ treatment followed (20.05 cm, 19.94 cm, 19.59 cm, 18.26 cm and 18.22 cm, respectively) by $T_6$, $T_7$, $T_4$, $T_3$ and $T_2$ treatment, whereas the minimum length was recorded in (16.18 cm) $T_8$ treatment (Figure 10).

**Girth of individual fruit (cm)**

In case of girth of brinjal fruit, significant differences among the treatments was found at 116 DAT. The maximum girth of healthy fruit (15.77 cm) was recorded from $T_5$ treatment followed by $T_6$ (15.49 cm), $T_4$ (14.89 cm), $T_7$ (14.47 cm), $T_2$ (14.19 cm), and $T_3$ (13.99 cm) treatment, whereas, the minimum girth of healthy fruit (12.55 cm) was recorded from $T_8$ treatment which showed significant differences from $T_5$ and $T_6$ treatment and followed (13.28 cm) by $T_1$ treatment (Figure 10).




[$T_1$= Cultural method + mechanical control; $T_2$= Braconid wasps @ 20-25/plot + Sanitation; $T_3$= Sanitation + Funnel Pheromone trap; $T_4$= Sanitation + Sevin 50 WP @ 1.0g/L; $T_5$= Success 2.5 EC @ 0.5 ml/L of water + Pheromone trap; $T_6$= Spinosad 45% SC @ 0.01% + Funnel Pheromone trap; $T_7$= Sanitation + *Trichogramma evanesence* @ 1 card/plot (1000 eggs per card) $T_8$= Untreated control]

**Figure 10:** Effect of different treatments against brinjal shoot and fruit borer (BSFB) in terms of length, girth and weight of single fruit at 116 DAT.

### Single Fruit at 123 DAT

### Individual fruit weight (g)

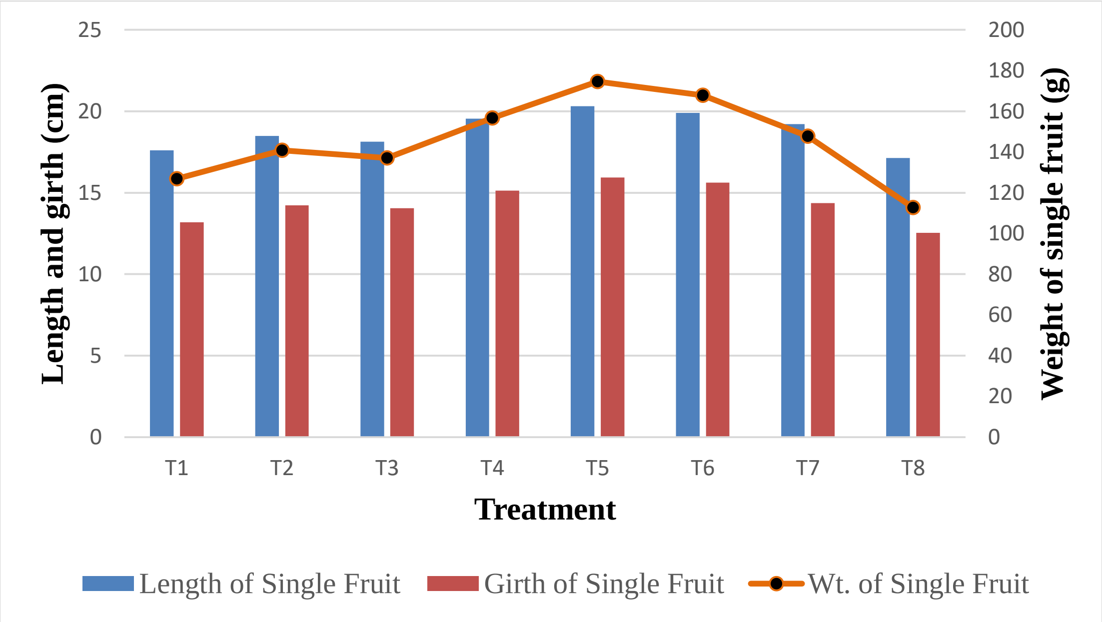
From Figure 11, it was observed that at 123 DAT the highest weight of individual fruit weight (174.63 g) was recorded from $T_5$ treatment which was statistically similar with (167.89 g and 156.67 g, respectively) to $T_6$ and $T_4$ treatment. On the other hand, the lowest weight (112.78 g) was recorded from $T_8$ treatment which was similar with (126.89 g and 137.0 g, respectively) to $T_1$ and $T_3$ treatment.

### Length of individual fruit (cm)

The maximum length of healthy fruit (20.32 cm) was found from $T_5$ treatment closely followed (19.90 cm, 19.55 cm and 19.21 cm, respectively) by $T_6$, $T_4$, and $T_7$ treatment, whereas the minimum length (16.66 cm) was found when plot remained untreated followed by $T_1$ treatment (17.61 cm) (Figure 11).

## Girth of individual fruit (cm)

In case of girth of brinjal fruit, there was significant differences among the treatments at 123 DAT. The maximum girth of healthy fruit (15.94 cm) was recorded from $T_5$ treatment closely followed (15.63 cm and 15.13 cm, respectively) by $T_6$ and $T_4$ treatment, whereas, the minimum girth of healthy fruit (12.54 cm) was recorded from $T_8$ treatment followed by $T_1$ treatment (13.19 cm). (Figure 11).




[$T_1$= Cultural method + mechanical control; $T_2$= Braconid wasps @ 20-25/plot + Sanitation; $T_3$= Sanitation + Funnel Pheromone trap; $T_4$= Sanitation + Sevin 50 WP @ 1.0g/L; $T_5$= Success 2.5 EC @ 0.5 ml/L of water + Pheromone trap; $T_6$= Spinosad 45% SC @ 0.01% + Funnel Pheromone trap; $T_7$= Sanitation + *Trichogramma evanesence* @ 1 card/plot (1000 eggs per card) $T_8$= Untreated control]

**Figure 11:** Effect of different treatments against brinjal shoot and fruit borer (BSFB) in terms of length, girth and weight of single fruit at 123 DAT.

## Single Fruit at 130 DAT

## Individual fruit weight (g)

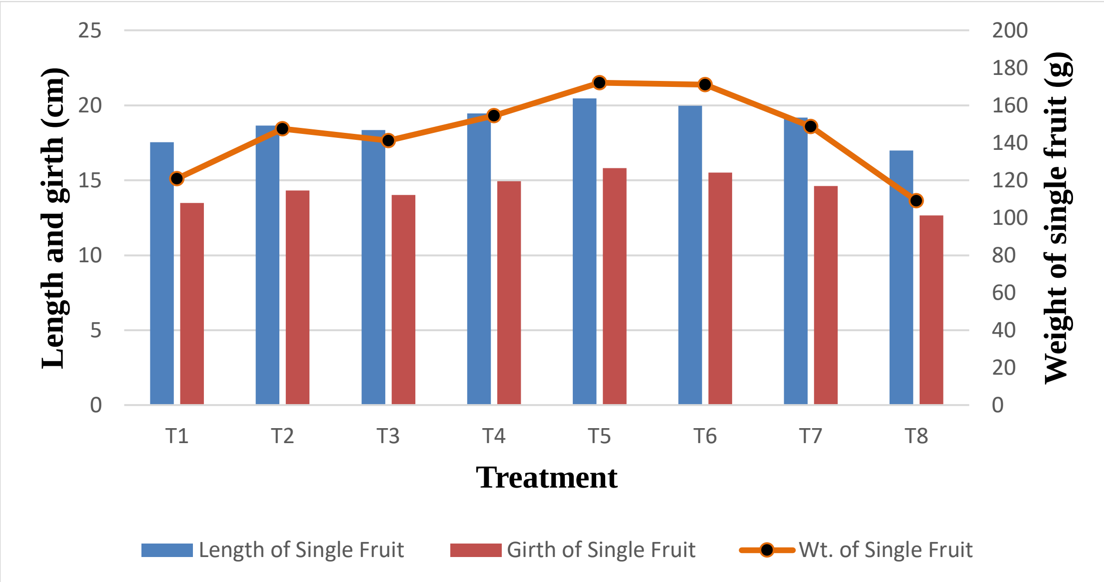
From Figure 12, it was observed that at 130 DAT the highest weight of individual fruit (172.11 g) was recorded from $T_5$ treatment followed (171.11 g, 154.44 g, 148.67 g, 147.45 g and 141.22 g, respectively) by $T_6$, $T_4$, $T_7$, $T_2$ and $T_3$ treatment. On the other hand, the lowest weight (109.05 g) was recorded from $T_8$ treatment which showed statistically similarity with (120.89 g) $T_1$ treatment and showed significant differences from rest of the treatment.

### Length of individual fruit (cm)

The maximum length of healthy fruit (20.47 cm) was found from $T_5$ treatment which was numerically different from $T_6$ (19.98 cm), $T_4$ (19.47 cm), $T_7$ (19.18 cm), $T_2$ (18.65 cm), $T_3$ (18.35) and $T_1$ (17.55 cm) and showed significant difference from $T_8$ treatment from which the minimum length (16.50 cm) of individual fruit was recorded (Figure 12).

### Girth of individual fruit (cm)

In case of girth of brinjal fruit, significant difference was found among the treatments at 130 DAT. The maximum girth of healthy fruit (15.82 cm) was recorded from $T_5$ treatment followed (15.52 cm, 14.93 cm, 14.61 cm, and 14.32 cm, respectively) by $T_6$, $T_4$, $T_7$ and $T_2$ treatment, whereas, the minimum girth of healthy fruit (12.65 cm) was recorded from $T_8$ treatment followed by $T_1$ treatment (13.48 cm). (Figure 12).




[$T_1$= Cultural method (clean cultivation to keep the plot free from weeds and debris to discourage pupation of insect); + mechanical control method (removal of infested roots, shoots and fruits) at the 7 days interval $T_2$= Braconid wasps at the rate of 20-25/plot at weekly interval + field sanitation; $T_3$= Sanitation at the 7 days interval + using Funnel Pheromone trap; $T_4$= Field sanitation + Spraying Sevin 50 WP @ 1.0g/ at the 7 days interval; $T_5$= Spraying Success 2.5 EC @ 0.5 ml/L of water at the 7 days interval + using Pheromone trap; $T_6$= Spraying Spinosad 45% SC @ 0.01% at 20 days interval + using Funnel Pheromone trap; $T_7$= Sanitation + *Trichogramma evanesence* at the rate of 1 card/plot at weekly interval (1000 eggs per card) $T_8$= Untreated control]

**Figure 12:** Effect of different treatments against brinjal shoot and fruit borer (BSFB) in terms of length, girth and weight of single fruit at 130 DAT.

### 4.6. Yield of fruit

### 4.6.1 Yield plot$^{-1}$ (kg)

Yield per plot showed statistically significant differences due to different bio-rational based management as treatments in controlling brinjal shoot and fruit borer of brinjal. Highest yield per plot (33.99 kg) was found in $T_5$ treatment which was statistically similar (32.33 kg) with $T_6$ treatment and followed (28.49 kg and 27.43 kg, respectively) by $T_4$ and $T_7$ treatment, while the lowest yield per plot (14.19 kg) was recorded in $T_1$ treatment (Table 20).

### 4.6.2 Yield hectare$^{-1}$ (ton)

Some bio-rational based management against BSFB showed significant difference in terms of yield per hectare of brinjal (Table 20). The highest yield per hectare (56.65 ton) was found in $T_5$ treatment which was statistically similar (53.88 ton) with $T_6$ treatment and significantly different from rest of the treatment, whereas the lowest yield per hectare (23.66 ton) was recorded in $T_8$ treatment where plot remained untreated (Table 20).

In terms of increased over control (%), estimated for some bio-rational based managements including bio-control agents and the highest value (139.42%) was recorded for the treatment $T_5$ followed (127.73%, 100.65% and 93.23%, respectively) by $T_{6,}$ $T_{4,}$ and $T_7$ treatment, whereas the lowest value (40.30%) was recorded in $T_1$ treatment (Table 20).

Mainali *et al.* (2013) also found Spinosad 45 SC as the most viable bio-rational options for *L. orbonalis* management among Spinosad 45 SC, Cypermetrhrin, Btk, Nimbecidine, Anosom, and CFE treatment and the marketable yield increment over untreated control was the highest in Spinosad 45 SC (275%) followed by Cypermetrhirn (212%), Btk (188%), Nimbecidine (176%), Anosom (142%), CFE (59%), respectively.

Dutta *et al*. (2011), also showed the similar type of result that the use of pheromone trap starting from 15 days after transplanting till final harvest gave substantial protection and 49.71% increase in yield over control.

**Table 20: Yield of brinjal from different treatments against BSFB during Rabi season, 2018-19**

| Treatment | Yield of fruit | | |
|---|---|---|---|
| | **Yield per plot (kg)** | **Yield per hectare (ton)** | **Increase over control (%)** |
| **$T_1$** | 19.92 d | 33.20 d | 40.30 |
| **$T_2$** | 25.10 c | 41.84 c | 76.83 |
| **$T_3$** | 24.02 c | 40.04 c | 69.23 |
| **$T_4$** | 28.49 b | 47.47 b | 100.65 |
| **$T_5$** | 33.99 a | 56.65 a | 139.42 |
| **$T_6$** | 32.33 a | 53.88 a | 127.73 |
| **$T_7$** | 27.43 b | 45.72 b | 93.23 |
| **$T_8$** | 14.19 e | 23.66 e | -- |
| **$LSD_{(0.05)}$** | 2.10 | 3.50 | -- |
| **CV(%)** | 4.67 | 4.67 | -- |

[$T_1$= Cultural method (clean cultivation to keep the plot free from weeds and debris to discourage pupation of insect); + mechanical control method (removal of infested roots, shoots and fruits) at the 7 days interval $T_2$= Braconid wasps at the rate of 20-25/plot at weekly interval + field sanitation; $T_3$= Sanitation at the 7 days interval + using Funnel Pheromone trap; $T_4$= Field sanitation + Spraying Sevin 50 WP @ 1.0g/ at the 7 days interval; $T_5$= Spraying Success 2.5 EC @ 0.5 ml/L of water at the 7 days interval + using Pheromone trap; $T_6$= Spraying Spinosad 45% SC @ 0.01% at 20 days interval + using Funnel Pheromone trap; $T_7$= Sanitation + *Trichogramma evanesence* at the rate of 1 card/plot at weekly interval (1000 eggs per card) $T_8$= Untreated control]

# CHAPTER V

## SUMMARY AND CONCLUSION

The study was conducted to find out the effect of some botanicals and bio-control agents in controlling brinjal shoot and fruit borer in brinjal in the central farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh during the period from October, 2018 to March, 2019. Begun-706 (Hybrid variety) was used as the test crop of this experiment. The experiment consists of the following management practices: $T_1$= Cultural method (clean cultivation to keep the plot free from weeds and debris to discourage pupation of insect) + mechanical control method (removal of infested roots, shoots and fruits) at the 7 days interval, $T_2$= Braconid wasps at the rate of 20-25/plot at weekly interval + field sanitation, $T_3$= Sanitation at the 7 days interval + using Funnel Pheromone trap, $T_4$= Field sanitation + Spraying Sevin 50 WP @ 1.0g/L at 7 days interval, $T_5$= Spraying Success 2.5 EC @ 0.5 ml/L of water at 7 days interval + using Pheromone trap, $T_6$= Spraying Spinosad 45% SC @ 0.01% at 20 days interval + using Funnel Pheromone trap, $T_7$= Sanitation + *Trichogramma evanescens* at the rate of 1 card/plot at weekly interval (1000 eggs per card) and $T_8$= Untreated control.

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Significant difference was observed on the number of healthy and infested shoot, flower at 55, 70, 85, 100 and 115 DAT in controlling brinjal shoot and fruit borer (BSFB) by using some bio-rational based management including bio-control agents (parasitoids) as treatments.

Results revealed that in case of number of healthy and infested shoot per plant at 55, 70, 85, 100 and 115 DAT, the highest number of healthy shoot (11.33, 15.93, 20.87, 22.27 and 14.67, respectively) was observed in $T_5$ (Spraying Success 2.5 EC @ 0.5 ml/L of water + using Pheromone trap) whereas the lowest (4.40, 5.73, 7.27, 760, and 4.53, respectively) was in $T_8$ (Untreated control). Similarly, the number of lowest infested shoot (0.07, 0.20, 0.27, 0.40, and 0.27, respectively) was observed in $T_5$ (Spraying Success 2.5 EC @ 0.5 ml/L of water + using Pheromone trap) whereas the highest (0.60, 1.13, 1.80, 2.07 and 1.60 respectively) was in $T_8$ (Untreated control).

In relation to the % shoot infestation, the lowest infested shoot per plant in number at 55, 70, 85, 100 and 115 DAT (0.59%, 1.24%, 1.26%, 1.78% and 1.79%, respectively) were recorded from $T_5$ (Spraying Success 2.5 EC @ 0.5 ml/L of water + using Pheromone trap) whereas the highest infested fruit per plant in number (12.14 %, 16.65 %, 20.01%, 21.36% and 26.31 % respectively) were recorded from $T_8$ (Untreated control).

In relation to the shoot infestation reduction over control (%) by number, the highest reduction of infestation at 55, 70, 85, 100 and 115 DAT (95.14%, 92.55%, 93.70%, 91.67% and 93.20%, respectively) were recorded from $T_5$ (Spraying Success 2.5 EC @ 0.5 ml/L of water + using Pheromone trap) whereas the lowest (21.91%, 44.08%, 41.58%, 46.25% and 41.20%, respectively) were recorded from $T_1$ (Cultural + mechanical control method).

Results revealed that in case of number of healthy and infested flowers per plant at 55, 70, 85, 100 and 115 DAT the highest number of healthy flowers (13.33, 26.73, 34.07, 28.73 and 22.40, respectively) was observed in $T_5$ (Spraying Success 2.5 EC @ 0.5 ml/L of water + using Pheromone trap) whereas the lowest (5.00, 10.67, 15.07, 12.67, and 7.00, respectively) was in $T_8$ (Untreated control). Similarly, the number of lowest infested flower (1.00, 2.73, 4.40, 3.03, and 2.00 respectively) was observed in $T_5$ (Spraying Success 2.5 EC @ 0.5 ml/L of water) whereas the highest (2.33, 6.07, 9.67, 7.93 and 5.33, respectively) was in $T_8$ (Untreated control).

In relation to the % flower infestation, the lowest infested flower per plant in number at 55, 70, 85, 100 and 115 DAT (6.98%, 9.34%, 11.48%, 9.65% and 8.26%, respectively) were recorded from $T_5$ (Spraying Success 2.5 EC @ 0.5 ml/L of water + using Pheromone trap) whereas the highest infested flower per plant in number (31.89 %, 36.35 %, 39.15%, 38.50% and 43.28 %, respectively) were recorded from $T_8$ (Untreated control).

In relation to the flower infestation reduction over control (%) by number, the highest reduction of infestation at 55, 70, 85, 100 and 115 DAT (78.11%, 74.31%, 70.68%, 74.94% and 80.91%, respectively) were recorded from $T_5$ (Spraying Success 2.5 EC @ 0.5 ml/L of water + using Pheromone trap) whereas the lowest

(36.38%, 25.50%, 25.34%, 24.73% and 30.15%, respectively) were recorded from $T_1$ (Cultural + mechanical control method).

Results revealed that in case of number of healthy and infested fruit at 88, 95, 102, 109, 116, 123 and 130 DAT the highest number of healthy fruit (8.67, 13.33, 20.33, 17.67, 11.67, 9.67 and 6.67, respectively) was observed in $T_5$ (Spraying Success 2.5 EC @ 0.5 ml/L of water) whereas the lowest (3.33, 4.67, 5.33, 4.67, 14.33, 2.67 and 1.00, respectively) was in $T_8$ (Untreated control). Similarly, the number of lowest infested fruit (0.67, 1.33, 2.00, 1.33, 1.33, 0.67 and 0.33, respectively) was observed in $T_5$ (Spraying Success 2.5 EC @ 0.5 ml/L of water + using Pheromone trap) whereas the highest (2.00, 4.33, 6.67, 6.33, 6.33, 4.00 and 1.67, respectively) was in $T_8$ (Untreated control).

In relation to the % fruit infestation, the lowest infested fruit in number at 88, 95, 102, 109, 116, 123 and 130 DAT (7.24%, 9.20%, 8.97%, 7.03% , 8.36%, 6.54% and 4.77% respectively) were recorded from $T_5$ (Spraying Success 2.5 EC @ 0.5 ml/L of water + using Pheromone trap) whereas the highest infested fruit per plant in number (37.55%, 48.17%, 55.58%, 57.63%, 57.63%, 60.04% and 62.55%, respectively) were recorded from $T_8$ (Untreated control).

In relation to the fruit infestation reduction over control (%) by number, the highest reduction of infestation at 88, 95, 102, 109, 116, 123 and 130 DAT (80.72 %, 80.90 %, 83.86%, 87.80%, 85.49%, 89.11% and 92.37 %, respectively) were recorded from $T_5$ (Spraying Success 2.5 EC @ 0.5 ml/L of water + using Pheromone trap) whereas the lowest (23.83%, 34.96%, 30.39%, 34.88% , 33.78%, 33.33% and 31.32%, respectively) were recorded from $T_1$ (Cultural + mechanical control method).

Results revealed that in case of weight of healthy and infested fruit at 88, 95, 102, 109, 116, 123 and 130 DAT the highest weight of healthy fruit (1463.00 g, 2299.30 g, 3558.00 g, 3120.00 g, 2578.30 g, 1673.00 g and 1159.30 g, respectively) was observed in $T_5$ (Spraying Success 2.5 EC @ 0.5 ml/L of water + using Pheromone trap) whereas the lowest (454.30 g, 644.30 g, 738.00 g, 642.30 g, 636.30 g, 350.30 g and 118.30 g, respectively) was in $T_8$ (Untreated control). Similarly, the weight of lowest infested fruit (92.00 g, 200.67 g, 308.67 g, 198.67

g, 199.33 g, 97.67 g and 45.67 g, respectively) was observed in $T_5$ (Spraying Success 2.5 EC @ 0.5 ml/L of water) whereas the highest (242.33 g, 522.33 g, 828.67 g, 694.33 g, 650.33 g, 403.00 g and 172.00 g, respectively) was in $T_8$ (Untreated control).

In relation to the % fruit infestation, the lowest infested fruit in weight at 88, 95, 102, 109, 116, 123 and 130 DAT (5.93%, 8.11%, 8.00%, 5.99% , 7.20%, 5.51% and 3.81%, respectively) were recorded from $T_5$ (Spraying Success 2.5 EC @ 0.5 ml/L of water + using Pheromone trap) whereas the highest infested fruit per plant in weight (34.78%, 44.78%, 52.90%, 52.02%, 50.60%, 53.50% and 59.22%, respectively) were recorded from $T_8$ (Untreated control).

In relation to the fruit infestation reduction over control (%) by weight, the highest reduction of infestation at 88, 95, 102, 109, 116, 123 and 130 DAT (82.95 %, 81.89 %, 84.88%, 88.49%, 85.77%, 89.70% and 93.57%, respectively) were recorded from $T_5$ (Spraying Success 2.5 EC @ 0.5 ml/L of water + using Pheromone trap) whereas the lowest (22.25%, 33.34%, 36.20%, 36.24%, 35.69%, 34.99% and 34.95%, respectively) were recorded from $T_1$ (Cultural + mechanical control method).

Yield contributing characters and yield of brinjal showed a statistically significant difference by using some bio-rational based management including bio-control agents (parasitoids) as treatments at 88, 95, 102, 109, 116, 123 and 130 DAT. The highest weight of individual fruit weight (170.00 g, 170.40 g, 173.34 g, 174.56 g, 174.00 g, 174.63 g and 172.11 g, respectively) was obtained in $T_5$ treatment and the lowest weight (133.23 g, 129.87 g, 130.45 g, 121.32 g, 116.78 g, 112.78 g and 109.05 g, respectively) in $T_8$ treatment. The maximum length of healthy fruit (19.93 cm, 20.02 cm, 20.14 cm, 20.29 cm, 20.39 cm, 20.32 cm and 20.47 cm, respectively) was found in $T_5$ treatment, whereas the minimum length (17.86 cm, 17.81 cm, 17.29 cm, 17.02 cm, 17.00 cm, 17.13 cm 16.98 cm, respectively) in $T_8$ treatment. The maximum girth of healthy fruit (15.01 cm, 15.53 cm, 15.25 cm, 15.85 cm, 15.77cm, 15.94cm and 15.82 cm, respectively) was found in $T_5$ treatment and the minimum girth (14.07 cm, 13.93 cm, 13.10 cm, 12.88 cm, 12.55 cm, 12.54 cm and 12.65 cm, respectively) in $T_8$ treatment.

The highest yield per plot (33.987 Kg) was obtained in $T_5$ treatment which statistically similar with $T_6$ (32.33 Kg) treatment and the lowest yield per plot (14.19 Kg) was recorded in $T_8$ treatment. The highest yield per hectare (56.65 ton) was obtained in $T_5$ treatment which statistically similar with $T_6$ (53.88 ton) treatment and the lowest yield per hectare (23.66 ton) was recorded in $T_8$ treatment.

# CONCLUSION

The present study revealed that the $T_5$= Spraying Success 2.5 EC @ 0.5 ml/L of water at 7 days interval + using Pheromone trap and $T_6$= Spraying Spinosad 45% SC @ 0.01% at 20 days interval + using Funnel Pheromone trap were the best treatments for increased yield per hectare of brinjal with decreased rate of fruit, shoot infestation and the reduced weight of infested fruits.

# RECOMMENDATION

- ✓ Considering the results of this experiments, it might be suggested that in most cases, the brinjal shoot and fruit borer, *Leucinodes orbonalis* could be suppressed by using different bio-rational management practices incuding bio-control agents for encouraging the activities beneficial.
- ✓ Further study is recommended to assess the bio-rational management practices of important agricultural pests along with various practices prevailing in different agro-ecosystem of Bangladesh.

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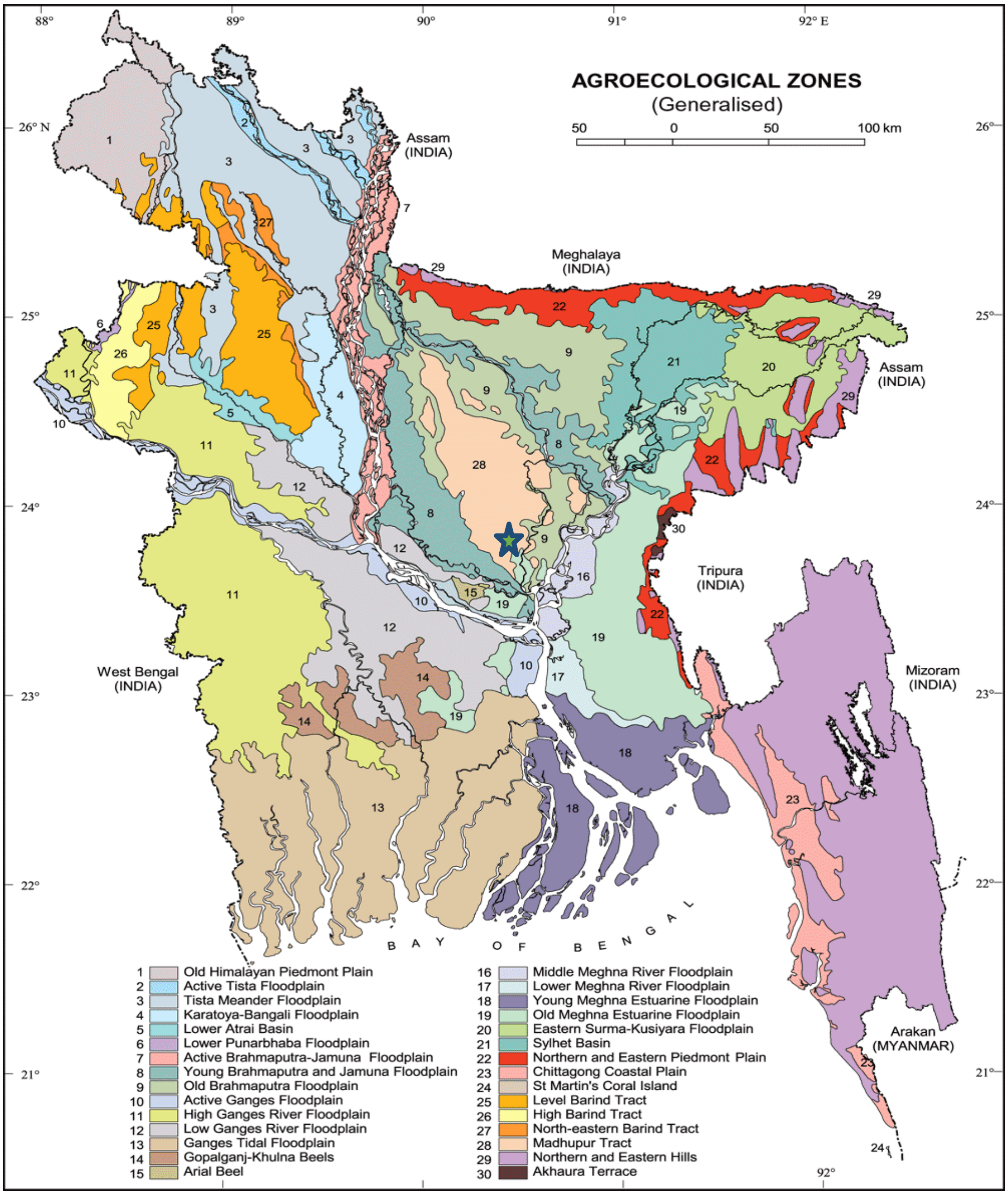
# APPENDICES

## Appendix I. Experimental location on the map of Agro-ecological Zones of Bangladesh




★ **The experimental site under the study**

**Appendix II. Characteristics of soil of experimental site is analyzed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka**

**A. Morphological characteristics of the experimental field**

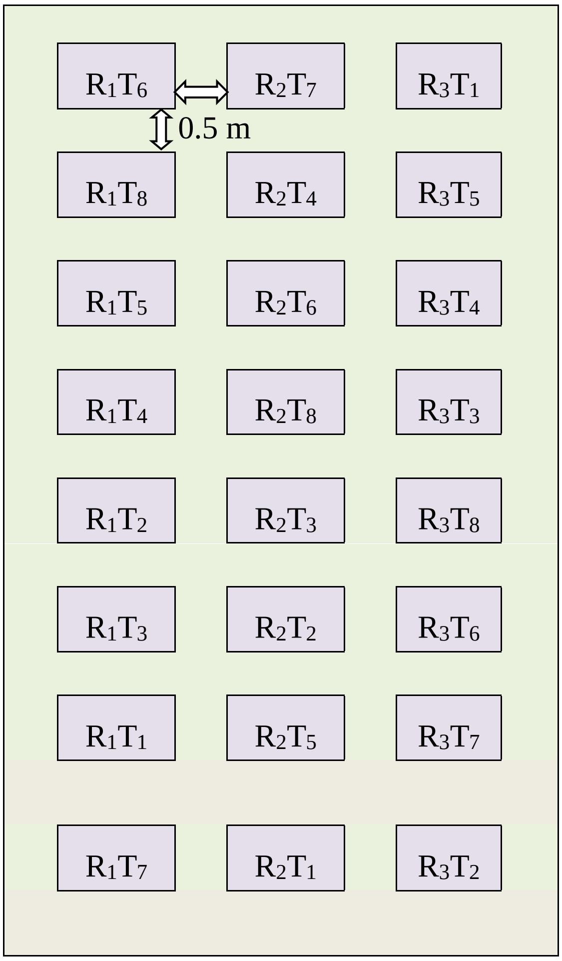
| Morphological features | Characteristics |
|---|---|
| Location | Agronomy Field laboratory, SAU, Dhaka |
| AEZ | Madhupur Tract (28) |
| General Soil Type | Shallow red brown terrace soil |
| Land type | Medium High land |
| Soil series | Tejgaon |
| Topography | Fairly leveled |
| Flood level | Above flood level |
| Drainage | Well drained |

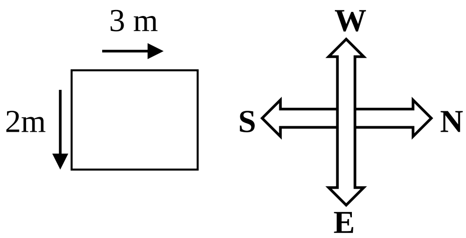
## B. Physical and chemical properties of the initial soil

| Characteristics | Value |
|---|---|
| % Sand | 27 |
| % Silt | 43 |
| % clay | 30 |
| Textural class | silty-clay |
| pH | 5.6 |
| Organic carbon (%) | 0.44 |
| Organic matter (%) | 0.76 |
| Total N (%) | 0.03 |
| Available P (ppm) | 20.04 |
| Exchangeable K (me/100 g soil) | 0.11 |
| Available S (ppm) | 43 |

**Source**: SRDI

## Appendix III. Layout of the experimental plot



**Appendix IV. Monthly air temperature, relative humidity, total rainfall and Sunshine of the experimental site during November, 2018 to March, 2019**

| Year | Month | *Air temperature (ºC) | | *Relative humidity (%) | *Rain fall (mm) (total) | *Sunshine (hr) |
|---|---|---|---|---|---|---|
| | | Maximum | Minimum | | | |
| 2018 | November | 19.2 | 29.6 | 53 | 34.4 | 11 |
| 2018 | December | 14.1 | 26.4 | 50 | 12.8 | 11 |
| 2019 | January | 12.7 | 25.4 | 46 | 7.7 | 11 |
| 2019 | February | 15.5 | 28.1 | 37 | 28.9 | 11 |
| 2019 | March | 28.1 | 19.5 | 68 | 00 | 6.8 |

* Monthly average

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

**Appendix V. Analysis of variance of the data on shoot and flower per plant by number as influenced by some bio-rational managements in controlling BSFB at 55 DATS**

| Sources of Variation | Degrees of Freedom | Mean Square value of | | | | | |
|---|---|---|---|---|---|---|---|
| | | Shoot by number | | | Flower by number | | |
| | | Healthy | Infested | % Infestation | Healthy | Infested | % Infestation |
| Replication | 2 | 0.82 | 0.0003 | 0.02 | 8.00 | 0.007 | 19.21 |
| Treatment | 7 | 126.02** | 0.14** | 53.35** | 25.91** | 0.60** | 188.64** |
| Error | 14 | 10.76 | 0.002 | 1.21 | 0.22 | 0.04 | 3.47 |

**: Significant at 1% level of probability

**Appendix VI. Analysis of variance of the data on shoot and flower per plant by number as influenced by some bio-rational managements in controlling BSFB at 70 DATS**

| Sources of Variation | Degrees of Freedom | Mean Square value of | | | | | |
|---|---|---|---|---|---|---|---|
| | | Shoot by number | | | Flower by number | | |
| | | Healthy | Infested | % Infestation | Healthy | Infested | % Infestation |
| Replication | 2 | 1.82 | 0.003 | 1.14 | 0.59 | 0.11 | 5.63 |
| Treatment | 7 | 36.86** | 0.35** | 82.60** | 89.60** | 4.33** | 252.32** |
| Error | 14 | 1.72 | 0.007 | 1.95 | 3.97 | 0.31 | 7.22 |

**: Significant at 1% level of probability

**Appendix VII. Analysis of variance of the data on shoot and flower per plant by number as influenced by some bio-rational managements in controlling BSFB at 85 DATS**

| Sources of Variation | Degrees of Freedom | Mean Square value of | | | | | |
|---|---|---|---|---|---|---|---|
| | | Shoot by number | | | Flower by number | | |
| | | Healthy | Infested | % Infestation | Healthy | Infested | % Infestation |
| Replication | 2 | 0.72 | 0.006 | 2.30 | 5.38 | 0.11 | 2.82 |
| Treatment | 7 | 64.57** | 1.05** | 122.12** | 120.81** | 10.54 | 262.78** |
| Error | 14 | 2.69 | 0.02 | 2.17 | 8.05 | 0.75 | 10.41 |

**: Significant at 1% level of probability

**Appendix VIII. Analysis of variance of the data on shoot and flower per plant by number as influenced by some bio-rational managements in controlling BSFB at 100 DATS**

| Sources of Variation | Degrees of Freedom | Mean Square value of | | | | | |
|---|---|---|---|---|---|---|---|
| | | Shoot by number | | | Flower by number | | |
| | | Healthy | Infested | % Infestation | Healthy | Infested | % Infestation |
| Replication | 2 | 4.18 | 0.03 | 0.04 | 1.28 | 0.21 | 1.91 |
| Treatment | 7 | 72.09** | 1.002** | 127.72** | 84.61** | 8.52** | 275.90** |
| Error | 14 | 2.74 | 0.02 | 0.83 | 7.80 | 0.47 | 8.58 |

**: Significant at 1% level of probability

**Appendix IX. Analysis of variance of the data on shoot and flower per plant by number as influenced by some bio-rational managements in controlling BSFB at 115 DATS**

| Sources of Variation | Degrees of Freedom | Mean Square value of | | | | | |
|---|---|---|---|---|---|---|---|
| | | Shoot by number | | | Flower by number | | |
| | | Healthy | Infested | % Infestation | Healthy | Infested | % Infestation |
| Replication | 2 | 2.78 | 0.008 | 3.003 | 5.54 | 0.43 | 17.49 |
| Treatment | 7 | 35.56** | 0.78** | 199.07** | 84.14** | 4.20** | 419.05** |
| Error | 14 | 1.53 | 0.02 | 4.03 | 2.06 | 0.16 | 4.69 |

**: Significant at 1% level of probability

**Appendix X. Analysis of variance of the data on fruit per plant by number and weight as influenced by some bio-rational managements in controlling BSFB at 88 DATS**

| Sources of Variation | Degrees of Freedom | Mean Square value of | | | | | |
|---|---|---|---|---|---|---|---|
| | | Fruit by number | | | Fruit by weight | | |
| | | Healthy | Infested | % Infestation | Healthy | Infested | % Infestation |
| Replication | 2 | 0.24 | 0.04 | 9.32 | 13469 | 1370.5 | 3.53 |
| Treatment | 7 | 9.61** | 0.93** | 338.22** | 374510** | 12951.1** | 317.02 |
| Error | 14 | 0.74 | 0.03 | 4.35 | 18834 | 431.3 | 3.05 |

**: Significant at 1% level of probability

**Appendix XI. Analysis of variance of the data on fruit per plant by number and weight as influenced by some bio-rational managements in controlling BSFB at 95 DATS**

| Sources of Variation | Degrees of Freedom | Mean Square value of | | | | | |
|---|---|---|---|---|---|---|---|
| | | Fruit by number | | | Fruit by weight | | |
| | | Healthy | Infested | % Infestation | Healthy | Infested | % Infestation |
| Replication | 2 | 0.94 | 0.12 | 5.78 | 235 | 366.5 | 0.32 |
| Treatment | 7 | 25.67** | 3.02** | 503.82** | 934447** | 35313.7** | 447.20** |
| Error | 14 | 1.56 | 0.08 | 7.87 | 40541 | 1999.3 | 5.25 |

**: Significant at 1% level of probability

**Appendix XII. Analysis of variance of the data on fruit per plant by number and weight as influenced by some bio-rational managements in controlling BSFB at 102 DATS**

| Sources of Variation | Degrees of Freedom | Mean Square value of | | | | | |
|---|---|---|---|---|---|---|---|
| | | Fruit by number | | | Fruit by weight | | |
| | | Healthy | Infested | % Infestation | Healthy | Infested | % Infestation |
| Replication | 2 | 2.60 | 0.47 | 3.98 | 96140 | 5277.1 | 6.45 |
| Treatment | 7 | 75.60** | 7.40** | 729.56** | 2594938** | 89546.5** | 657.33** |
| Error | 14 | 2.34 | 0.16 | 5.91 | 64442 | 3703.5 | 2.70 |

**: Significant at 1% level of probability

**Appendix XIII. Analysis of variance of the data on fruit per plant by number and weight as influenced by some bio-rational managements in controlling BSFB at 109 DATS**

| Sources of Variation | Degrees of Freedom | Mean Square value of | | | | | |
|---|---|---|---|---|---|---|---|
| | | Fruit by number | | | Fruit by weight | | |
| | | Healthy | Infested | % Infestation | Healthy | Infested | % Infestation |
| Replication | 2 | 5.14 | 0.22 | 0.64 | 72897 | 3185.3 | 0.11 |
| Treatment | 7 | 53.43** | 9.18** | 805.31** | 1825256** | 87725.2** | 652.37** |
| Error | 14 | 1.98 | 0.18 | 2.86 | 49908 | 4091.8 | 3.36 |

**: Significant at 1% level of probability

**Appendix XIV. Analysis of variance of the data on fruit per plant by number and weight as influenced by some bio-rational managements in controlling BSFB at 116 DATS**

| Sources of Variation | Degrees of freedom | Mean Square value of | | | | | |
|---|---|---|---|---|---|---|---|
| | | Fruit by number | | | Fruit by weight | | |
| | | Healthy | Infested | % Infestation | Healthy | Infested | % Infestation |
| Replication | 2 | 1.07 | 0.07 | 2.42 | 13123 | 2829.0 | 2.08 |
| Treatment | 7 | 31.66** | 8.76** | 779.38** | 1202641** | 69827.8** | 596.17** |
| Error | 14 | 1.91 | 0.17 | 6.21 | 48229 | 3361.9 | 3.08 |

**: Significant at 1% level of probability

**Appendix XV. Analysis of variance of the data on fruit per plant by number and weight as influenced by some bio-rational managements in controlling BSFB at 123 DATS**

| Sources of Variation | Degrees of freedom | Mean Square value of | | | | | |
|---|---|---|---|---|---|---|---|
| | | Fruit by number | | | Fruit by weight | | |
| | | Healthy | Infested | % Infestation | Healthy | Infested | % Infestation |
| Replication | 2 | 0.44 | 0.09 | 9.86 | 12906 | 385.9 | 0.14 |
| Treatment | 7 | 15.79** | 4.00** | 926.53** | 575564** | 34934.7** | 736.44** |
| Error | 14 | 0.90 | 0.07 | 9.39 | 14533 | 1155.0 | 8.92 |

**: Significant at 1% level of probability

**Appendix XVI. Analysis of variance of the data on fruit per plant by number and weight as influenced by some bio-rational managements in controlling BSFB at 130 DATS**

| Sources of Variation | Degrees of freedom | Mean Square value of | | | | | |
|---|---|---|---|---|---|---|---|
| | | Fruit by number | | | Fruit by weight | | |
| | | Healthy | Infested | % Infestation | Healthy | Infested | % Infestation |
| Replication | 2 | 0.23 | 0.05 | 16.17 | 3822 | 345.38 | 3.65 |
| Treatment | 7 | 10.29** | 0.93** | 1057.35** | 359259** | 9425.57** | 959.74** |
| Error | 14 | 0.25 | 0.02 | 13.46 | 10213 | 421.42 | 10.89 |

**: Significant at 1% level of probability

**Appendix XVII. Analysis of variance of the data on single fruit per plant by weight, length and girth as influenced by some bio-rational managements in controlling BSFB at 88 and 95 DATS**

| Sources of Variation | Degrees of freedom | Mean Square value | | | | | |
|---|---|---|---|---|---|---|---|
| | | At 88 DATS | | | At 95 DATS | | |
| | | Wt. of Single fruit | Length of Single fruit | Girth of Single Fruit | Wt. of Single fruit | Length of Single fruit | Girth of Single Fruit |
| Replication | 2 | 441.85 | 27.88 | 2.36 | 29.92 | 12.41 | 4.35 |
| Treatment | 7 | 552.46** | 1.30** | $0.50^{NS}$ | 565.53** | 1.73** | $1.13^{NS}$ |
| Error | 14 | 361.19 | 3.00 | 3.71 | 440.68 | 4.55 | 2.60 |

**: Significant at 1% level of probability, $^{NS}$: Non-Significant

**Appendix XVIII. Analysis of variance of the data on single fruit per plant by weight, length and girth as influenced by some bio-rational managements in controlling BSFB at 102 and 109 DATS**

| Sources of Variation | Degrees of Freedom | Mean Square value | | | | | |
|---|---|---|---|---|---|---|---|
| | | At 102 DATS | | | At 109 DATS | | |
| | | Wt. of Single fruit | Length of Single fruit | Girth of Single Fruit | Wt. of Single fruit | Length of Single fruit | Girth of Single Fruit |
| Replication | 2 | 98.89 | 8.38 | 0.38 | 289.90 | 0.76 | 0.58 |
| Treatment | 7 | 651.57** | 3.18** | $1.85^{NS}$ | 1040.59** | 3.89** | $3.24^{NS}$ |
| Error | 14 | 410.98 | 4.91 | 3.38 | 372.86 | 6.25 | 3.47 |

**: Significant at 1% level of probability, $^{NS}$: Non-Significant

**Appendix XIX. Analysis of variance of the data on single fruit per plant by weight, length and girth as influenced by some bio-rational managements in controlling BSFB at 116 and 123 DATS**

| Sources of Variation | Degrees of Freedom | Mean Square value | | | | | |
|---|---|---|---|---|---|---|---|
| | | At 116 DATS | | | At 123 DATS | | |
| | | Wt. of Single fruit | Length of Single fruit | Girth of Single Fruit | Wt. of Single fruit | Length of Single fruit | Girth of Single Fruit |
| Replication | 2 | 263.62 | 2.04 | 8.99 | 548.86 | 4.17 | 13.14 |
| Treatment | 7 | 1161.62** | 4.60** | 3.49** | 1281.93** | 3.86** | 4.08** |
| Error | 14 | 351.09 | 5.75 | 2.42 | 214.22 | 4.33 | 1.44 |

**: Significant at 1% level of probability

**Appendix XX. Analysis of variance of the data on single fruit per plant by weight, length and girth as influenced by some bio-rational managements in controlling BSFB at 130 DATS**

| Sources of Variation | Degrees of freedom | Mean Square value | | |
|---|---|---|---|---|
| | | At 130 DATS | | |
| | | Wt. of Single fruit | Length of Single fruit | Girth of Single Fruit |
| Replication | 2 | 78.71 | 3.52 | 1.14 |
| Treatment | 7 | 1461.49** | 4.21** | 3.29** |
| Error | 14 | 332.38 | 5.07 | 2.87 |

**: Significant at 1% level of probability

**Appendix XXI. Analysis of variance of the data on yield per plot and yield per hectare as influenced by some bio-rational managements in controlling BSFB**

| Sources of Variation | Degrees of freedom | Mean Square value | |
|---|---|---|---|
| | | Yield per plot | Yield per hectare |
| Replication | 2 | 0.67 | 1.85 |
| Treatment | 7 | 125.30** | 348.06** |
| Error | 14 | 1.44 | 4.003 |

**: Significant at 1% level of probability