Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
www.entomoljournal.com
JEZS 2021; 9(1): 181-189

Received: 07-11-2020
Accepted: 09-12-2020

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Review on integrated management of brinjal shoots and fruit borer, *Leucinodes orbonalis* (Guenee)

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DOI: https://doi.org/10.22271/j.ento.2021.v9.i1c.8143

Abstract
Eggplant *Solanum melongena* is one of the most important vegetables of south Asia. It is the most important vegetable of hot and wet climatic zones. It is commercially very profitable vegetable crop to farmers. It has a wide range of bio chemicals, minerals, vitamins, proteins, calcium and phosphorus. Several insect pests attack the brinjal crop among those, *Leucinodes orbonalis* is the most obnoxious, destructive damaging pest to the brinjal .It is a key pest of brinjal, causes damage to shoots buds stems and fruits. Larva of this pest is the damaging stage to brinjal crop. Larvae bore inside the shoots petioles and fruits and reduce the crop yields up to 80% damage to fruits has been identified. This sitsuation has posed a hindrance to the farmers in commercial cultivation of eggplant; hence relevant literatures were collected, studied and reviewed regarding biology and management of borer. Available management tools are not being enough to control the population of this pest and in such condition it is needful to have a holistic approach towards IPM practices. In this article, several control measures for *L. orbonalis* including resistant varieties, cultural methods, physical and mechanical barriers, sex pheromones, bio-pesticides and bio-control agents; chemical and botanical means are outlined and evaluated with supportive facts and figures with reference to previous works and researches in this area.

Keywords: Egg-plant**,** *Leucinodes orbonalis*, life cycle, IPM, biological control agents

1. Introduction
Brinjal (*Solanum melongena* Linnaeus) or eggplant comes under the crop family Solanaceae ((Nightshade) and it is native to Indian Sub-continent (68). It is also known as eggplant in US, Austalia. In UK it is called as Aubergine and in South Asia and South Africa it is called as Brinjal (68). It is one of the widely used solanaceous vegetable crop by people and is being cultivated in India for the last 4000 years. Though brinjal is a summer crop, it is grown throughout the year under irrigated conditions. The crop is generally sown twice or thrice in a year, depending upon the irrigation facilities. Brinjal is the most popular and principle vegetable crop regarded as the "King of Vegetables" India is the second largest producer of brinjal in the world next to China. It is also grown as commercial and kitchen garden crop in India. It is highly cosmopolitan and popular vegetable grown as "Poor man's crop" in India. It is the most consumed and most sprayed vegetable in India, where it is grown on more than 5 lakh hectares, making it one of the main sources of cash for many farmers (68).
It is importance due to its nutritional, medicinal, as well as commercial value, 100gm edible portion of brinjal supplies 40 gm carbohydrates, 1.40gm of protiens, 0.30gm of mineral and vitamins A, B and C (68,69). The fruits of brinjal are the reasonable sources of vitamins and minerals and it is rich in total water soluble sugars, free reducing sugars, amide proteins among other nutrients.
The production of the crop is regulated by different biotic and abiotic factors and amongst those factors, insect-pests plays a pivotal role for lowering the yield of brinjal by attacking the crop right from the nursery stage to till harvesting. Generally farmers are depending on synthetic chemical pesticides to control insect pests which lead to the development of resistance by target pest with also a negative impact on natural enemies, therefore identification and conservation of natural enemies to control insect pest is very much essential. Based on infestation level 5 insect pests namely Jassid (*Amrasca biguttula*), Whitefly (*Bemisia tabaci*), Aphid (*Aphis gossypii*), Brinjal shoot and fruit borer (*Leucinodes orbonalis* and Hadda beetle (*Henosepilachna*

vigintioctopunctata) were observed as causing high infestation and categorized as regular and major insect pests of brinjal. Other insects' pests showed either moderate or less infestation level. Among the insect pests, Shoot and fruit borer, occurred on young tender shoots, the growing point and wilted dropping shoot, which ultimately withers and dries always. The infestation of this pest was initiated just after fruit setting and the infestation started from early vegetative to harvesting stage, Infestation of Hadda beetles were initiated just after transplanting of seedlings of the crop season, The sucking pests, Jassid, Whitefly, Aphids were recorded on vegetative to harvesting stage and they appeared 3-4 weeks after transplanting and remained active throughout the crop season. Mealy bugs *Coccidohystrix insolita* infestation was highest during full vegetative to harvesting stage. Leaf roller *Autoba olivacea* was active from early vegetative to late vegetative stage. Little leaf of brinjal is transmitted by brown leaf hopper, *Cestius phycitics.* It is a vector of little leaf of brinjal. Nymphs and adults suck cell sap from ventral side of leaf and inject toxins into the plant tissues and cause reduction in size of leaves, shortened petioles, excessive growth of branches general stunting of plants, conversion of floral parts into leafy structures and give the plants a bushy appearance and fruiting is rare. Some of the insects namely, Ash weevils, *Mylloceres discolor* Tobacco caterpillar, *Spodoptera litura* and Flea beetle, *Podagrica sp*. were observed on vegetative stage and different growth of the crop. Red cotton bug, *Dysdercus koenigi* was found occurred form the flowering to harvesting stage. Semilooper and grasshopper were noticed on vegetable stage. Five species of natural enemies were recorded namely, *Chrysoperla carnea*, *Cheilomenes sexmaculata Coccinella transversalis*, *Coccinella septumpunctata*, *Scymmus spp*. And three species of spiders were noticed i. e, *Lycosa spp.*, *Marpissa spp., Oxyopes spp*. Based on the infestation level five insect pests namely Jassid, *Amrasca biguttula biguttula*, Whitefly, *Bemisia tabaci* and Aphid, *Aphis gossypii*, shoot and fruit borer, *Leucinodes orbonalis* and Hadda beetles, *Henosepilachna vigintioctopunctata* were observed with highly infestation and categorized as regular and major insect pests of brinjal. Other insect pests showed either moderate or less infestation level (68,69).

Brinjal crop is attacked regularly or sporadically by at least 50 insect pests and Aphid, Jassids, Whitefly and shoot and fruit borer are categorized as major pests of regular occurrence reported by (68,69) Singh, 1983; which are in agreement with the present investation. However, with the decline in temperature, the population of brinjal fruit and shoot borer larvae also decreased and less infestation level (Kaur et. 2014) [25]. (68) also supported that brinjal is attacked by 142 species of insects, four species of mites and three species of nematodes in different countries of world. Most of insect pest's occurrence and infestation were mostly dependent on the climatic factors as well as growth stage of the crop. Among insect pests brinjal fruit and shoot borer is one of the most destructive obnoxious and damaging major key pest of egg plant in South and Southeast Asia. In Meghalaya reported that it damaged 26.3 – 62.5% fruit of eggplant. To control the major key pests of eggplant farmers injuriously applying insecticides and by this indiscriminate use of insecticides by farmers to control BFSB it leading to the development of resistance resurgence and environmental contamination, with view point of this the present review article is about how to manage these key pests by IPM.

2. Methodology: The data for this review paper was collected by the related journals article research proceedings annual reports, thesis, review reports, survey reports and library books, etc.

Taxonomic Classification

Common Name - Brinjal fruit and shoot borer

Leucinodes orbonalis was described and classified by Guenee in 1854 and Walker signed it as the sort types of the class Leuinodes in 1859 (CABI, 2007). (Fig.1)

Phylum:	Arthropoda
Class:	Insecta
Order:	Lepidoptera
Family:	Crambidae (Syn- Pyralidae)
Genus:	*Leucinodes*
Species:	*orbonalis*

3. Host Range: Generally BFSB has feed on brinjal crop beside this reported that to be the host of the plants belonging to Solanaceae family like tomato, chilly, potato and occasionally on the green pod of peas.

4. Distribution: This pest BSFB is generally occurring in the places having hot and moist atmosphere (68). It is the most destructive pest in the region of Asia especially in India, Pakistan, Srilanka, Nepal, Bangladesh, Thailand, Philippines, Cambodia, Laos and Vietnam (68).

5. Mark of identification and Life Cycle: BSFB has 4 developmental stages in the life history namely: Egg, larva, Pupa, Adult. Among this, larval stage is the longest stage followed by pupa. (Fig.2)

5.1Egg: Usually oviposition occurs at night time, Alam *et al*. (1982) [2] and Kavitha *et al*. (2008) [26] reported that a single female BFSB lays 5 to 242 eggs in her life stage. Generally eggs laid singly on the lower surfaces of the young leaves, green stems, flower buds, calyces of the fruits. According to CABI, 2007 reports eggs are laid during early morning singly or in small batches on the ventral surfaces of the leaves, the shape of egg is flat elliptical oval elongated somewhat in shape and the colour of the egg is creamy white at the timing of laying but before hatching colour of the egg changes to red. Brooding time of the egg varies in summer it takes 3 to 5 days and in winter it takes 7 to 8 days after this incubation period it hatch out as a dull white larvae (72). Ali and Sanghi (1962) [5]; Jat *et al*. (2003) [24]; Mehto *et al*. (1983) [35]; reported the pre ovipositional, ovipositional and post ovipositional periods as 1.1-2.1, 1.4-4.0 and 1.0-2.0 days respectively.

5.2 Larva: The damaging /destructive stage: Damage occurred by caterpillar having creamy white when but became light pink when full grown having length 18-23 mm. Generally larva undergoes 5 -6 instars, Atwal, (1976) [8] (72) (Jat *et al*. (2003) [24]; Harit and Shukla (2005) [23]; Patial *et al* 2007 [40]; Raina and Yadav (2017) [44, 45] and Sing (2001) [60]; observed the average duration of 1st,2nd,3rd,4th and 5th larval instars as 1-2,2-3,2-3,2-4 and 2-4 days respectively. Usually newly hatched larva bores into the petioles, midrib of large leaves and young tender shoots during vegetative stage but during reproductive phase larvae bores into the flower buds and also through the calyx it enters to the fruit. Newly hatched larva was tiny creamy or dirty white in colour and has dark brown or light black head, having three pairs of thoracic legs and 5 pairs of pro legs, 2nd

instar larvae looks like first instar larvae and it is quite larger in shape and somewhat dark in colour, 3rd instar larvae is longer than 2nd instar larvae and darker too and prothoracic legs are dark brown in colour. 4th instar larvae quite pinkish in colour, 5th instar larvae has pinkish brown colour having 3 distinct segments of thorax and 5 pairs of well-developed prolegs. (72) reported that: 1st instar larvae are found in bloom buds and blossoms, 2nd in stars are found in all susceptible plant parts, 3rd and 4th instar as are found in shoots and in most of the fruits also, 5th instar larvae found in fruits and it measures 18-23mm. One fruit of eggplant contains up to 20 larvae in Ghana (72).

5.3 Pupa: Pupal period of BSFB varies: in summer it undergoes 7-10 days while in winter it undergoes 13-15 days pupation (72). Pupation of this pests takes place generally in soil and also in dried shoots, leaves or plant refuse or derbies fallen on the ground. Butani and Verma (1976) [12] and Mehto *et al*. (1983) [35] reported that pupa is dark brown in colour with wider cephalic lobe and narrow anal end with 8 hook shaped fine spines at the posterior end of abdomen.

5.4 Adult: BSFB moth is white in colour with blackish brown spot on the dorsum of thorax and abdomen. Whitish wings and pinkish brown tinge and are tinged ringed with small hair along the apical and anal margin. First pair of wings is ornamented with a number of black, pale and light brown spots. The males of BSFB are smaller in size lesser in wing expanse and narrow or slender abdomen having tapered end posteriorly. Width of across spreading wings measure about 20-22 mm. Females of adult are bigger in size having more wing expanse than males and having broader abdomen with rounded posteriorly Jat *et al*., (2003) [24]. Raina and Yadav, (2017) [44, 45] reported that adults usually mates during night or early hours in the morning, mating period are varies as follows: Pre-mating: 6-9 hours and Post-mating: 4-6 days. The adults remained in mating position period for 30-49 minutes, Alam *et al*. (1982) [2]; Jat *et al*. (2003) [24] and Singh (2001) [60] observed that male and female moths of lived for 1-3 and 2-5.8 days respectively. Lal and Ahmed (1965) [30]; Alam *et al*.(1982) [2] ; Atwal (1976) [8] and Mehto *et al*.(1983) [35] stated that BSFB completes its life cycle in 19-43 days. Newly formed adult usually found on the lower leaf surfaces Alam *et al. (*2003) [3, 4] this pest completed 5 overlapping generations per year.

6. Nature of damage

BSFB larvae is the damaging destructive stage of the eggplant, within one hour of hatching larva bores to the nearest tender shoots, flower, fruits of eggplant, after entering larvae plug or close the entrance hole with black coloured excreta. This caterpillar makes tunnels and bores inside the petioles and midribs of leaves leads to wilting of the shoots. Presence of wilted shoots is the sign of BSFB attack or infestation, this leads to reduction in the growth of the plant by causing dead hearts and reduces the number of fruits and size also, and this damaged fruits are unfit for market quality and also unfit for human consumption because of this BSFB attack growers may face tremendous losses. Damage fruits have loss 60 percent nutritive content and Vitamins. Such infected product is unfit for human consumption having no market value. (Fig.3)

7. Management

7.1 Cultural and mechanical methods: Cultural practices like crop rotation, intercropping, pruning and removal of alternate hosts are important crop management practices to obtain better yield and reduce pest infestation to some extent. Alternate hosts like Potato, Tomato, Chilly and other vegetables of Solanaceae family should be removed from the periphery of Brinjal field since they provide shelter to *L. orbonalis* and provide suitable environment for the growth and development of the insect (72). Brinjal stubbles and remains of previous season crop serve as suitable site for egg laying and growth of this insect (72). Removal of stubbles and alternate host are proved to be effective to minimize the spread of this pest. Similarly, pruning of infested twigs and branches, removal of unwanted plants, reducing the highly dense population and removing wilted plant parts help in preventing the spread of *L. orbonalis* (72). Since pruning and pinching have no negative effects on the growth and development of Brinjal, the wilted damaged shoot should be periodically pinched or pruning should be done. They must be collected and buried or burned to reduce pest infestation (72). The damaged eggplant shoots and fruits should be removed by different ways at regular intervals without disturbing the healthy fruits and shoots and minimizing the spread of the pest which can help in reducing the pest infestation to great extent (72). Suitable nylon net barrier at suitable heights are also frequently used by the farmers for commercial cultivation of Brinjal which helps to keep the adult insects away from the cultivated field. It is always advised to combine two or more methods of protection such as use of barriers combined with manual destruction of the pest significantly reduced the damage than any single methods. When use of barrier + clipping practices was followed instead of using barrier alone, highest marketable fruit yield as well as lowest fruit infestation for number and weight was obtained (69,71) reported BH-1, BH-2 and Punjab Barsati cultivars had significantly higher marketable fruit yield and total fruit yield in net house condition than any other varieties. So, mechanical barrier can also be regarded as one of the most efficient technologies of *L. orbonalis* management and it has resulted better management of pest population

7.2 Screening of resistance verities against BSFB

Resistant varieties are considered as the first line of defense against pests and one of the safest methods which are compatible with other control measures. Several attempts have been made to cultivate resistant genotype of Brinjal against *L. orbonalis*, but no cultivars with appreciable resistance have been developed so far. In Nepal, Very few researches and breeding techniques have been practiced to develop a resistant genotype suitable for its geography. However many research activities are being done in other nations to search for true resistant cultivar of Brinjal against this pest. Thin fruits, short with lower number of calyx, Shoots with small diameter and thin stems and branches are the tolerant characters of resistant genotypes (71). The plants with long and narrow fruits and long hairs on the shoots prevented the insect to lay eggs on the shoot and fruits. Such characters are of major preference while researching on resistant cultivars of Brinjal for L. orbonalis. Eggplant accessions EG058, BL009, ISD 006 and Turbo (a commercial hybrid) are found to have substantial level of resistance to L. orbonalis as reported by (71) Local cultivars like Pusa Purple Long - 74 and Navkiran were found to be promising varieties in semi-arid region of Rajasthan and they had low shoot and fruit infestation as well Mathur *et al* (2012) [32]. In a field screening of different genotypes of Brinjal, Thapa., *et al*. [19] discovered that this pest was found in highest density in F1 long and F1 round hybrids but other popular varieties like Nurki, Neelam Long and Pusa Purple Long were

the least preferred genotypes in Nepal. Among the tested genotypes, Nurki, Neelam Long and Pusa Purple Long were least damaged and low infestation was seen due to *L. orbonalis*. (69) reported that Pusa Kranti and Nurki varieties of Brinjal were least infested than Pusa Purple Long (PPL) and proved to be even better than local landraces.

7.3 Application of 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) [32]. The major component of BFSB sex pheromone was identified and synthesized in laboratory was (E)-11-hexadecenyl acetate (E11-16: Ac) in China (69,71). 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 (69) 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 (69) Alam *et al* (2003) [3, 4], (69,71). 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) [32]. 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) [20], 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) [32].

7.4 Efficacy of microbial, botanical and natural enemies against *L. orbonalis*

Successful control of a pest species by means of another living organism that is encouraged and disseminated by man is called Biological control. In this, natural enemies are introduced, encouraged and multiplied by artificial means and disseminated by man with his own efforts instead of leaving it to natural condition.

The natural enemies of insects are 3 P's as follows:

1. Predators
2. Parasitoids
3. Pathogens include virus, bacteria fungi, protozoans and nematodes.

Because of the host specific and crop specific character of bio control agents, in all over the world found 16 parasitoids, 3 predators and 3 entomopathogenic species on *L. orbonalis.* Among these *T. chilonis* Ishii is the most effective egg parasitoid of BFSB. Application of Microbes, Bio-agents as well as plant originated insecticides having most eco-friendly approach of IPM and a good control measure against L. orbonalis. They have minimum effect on non-target organisms and very little effect on human health. Several bio-control agents like Bacteria, *Nuclear Polyhedrosis Viruses* (NPV), Fungi (*Beauveria bassiana*) are tested against this pest in Brinjal. According to (69,71) lowest mean shoot infestation was seen by the use of *Bacillus thuringiensis* (13.31% shoot infestation) and Neem oil (15.05% shoot infestation) respectively. At the same time, *M. anisopliae* (15.1% shoot infestation) and *B. bassiana* (15.37% shoot infestation) were at par with each other. They were also significantly superior over untreated control plots with as high infestation as 25.68%. The use of Neem recorded minimum fruit infestation of 16.36% while *M. anisopliae*, *B. thuringiensis* and *B. bassiana* were not so effective treatments for fruit infestation but all of them were superior over untreated control plots (35.23% fruit infestation). Among the bio-pesticides, lowest shoot and fruit infestation was seen by the foliar application of Bt @ 2 g/litre of water along with the highest marketable yield followed by NSKE (5%) Nayak *et al*. (2013) The most effective treatments was the application of 5% NSKE because it was able in reducing the whitefly and shoot and fruit borer infestation on Brinjal when applied in different spray schedule. The same treatment also recorded maximum yield of Brinjal Mandal *et al*. (2010). Similarly, although the efficacy of NPV is lower, it can be used as a bio control agent (69). There are many biocontrol agents available to use for crops against insects because of their host specific and crop specific nature and it is found that sixteen parasitoids, three predators and three entomo-pathogenic species are reported as natural enemies of *L. orbonalis* from all over the world (69,71). Among all of these bio control agents, *Trichogramma chilonis* Ishii is demonstrated as the most effective and it is an egg parasitoid which attacks the egg stage of the target pest (69,71). Endo parasitoids, like *Camptothlipsis sp., Campyloneurus mutator* Fabricius, *Chelonus* sp. and *Cremastus* (Trathala) *flavoorbitalis* (Cameron) (Hymenoptera) etc have been identified as natural enemies against target pest (69). The Botanical oil products were also found to be efficient for management of BSFB. When Brinjal was cultivated as Kharif and Rabi Crop in different seasons, Neem oil @ 2 percent was the best treatment in both condition with 60.2% and 59.91% reduced damage respectively supporting the previous results of many researchers. This result was followed by Nimbecidine @ 2 ml/litre with 57.42% reduced damage [40]. All the botanicals, such as Ecogold @ 10 ml/litre of water; Alata soap @ 5 g/litre of water etc were reported to reduce the pest infestation to significant degree. Further, other botanicals such as Garlic @ 30 g/litre of water; Neem oil @ 3 ml/l of water; Papaya leaves @ 92 g/litre of water and Wood ash @ 10 g/plant were also tested in different research activities and they turned out to produce significant result in terms of reduction of pest population of Brinjal Fruit and Shoot Borer including other pest of Brinjal Mochiah *et al*. (2011). Similarly, Endosulfan with 14.23 percent fruit damage, both iluppai oil and pungam oil were significantly effective in controlling shoot and fruit borer with 15.93 percent and 16.3 percent fruit damage respectively Mathur *et al*. (2012) [32]. (69) reported that Neem leaf extract @50 g/L water was highly effective against *L. orbonalis*. Many workers previously have reported the efficacy of different biocontrol agents and botanical pesticides against this pest which can help to minimize the pest damage and increase yield significantly. Because of its higher rate of parasitism and availability in all regions this *Trathala flavoorbitalis* becomes one of the potential biological control of BFSB and with this *Goryphus nursei* (Ichnuemonidae: Hymenoptera) this was recorded in UP and this act as active parasitoid in winter, and also *Pristomerus testaceus, Elasmus corbetti* and *Euagathis sp*, reported as natural enemies in Thailand. (Table.1) (69,71), reported with a small paper card

having 250-400 eggs of *T. chilonis* tied to the plants or small poles in the fields about 10 ft height from ground level, after sometime parasitoids released from this card and start preying on the BFSB, this biological control method by using this small paper card saving a minimum of rupees 25,000/ha, as weekly cost of this method will be only 150-200rs against 1500-2000 of each weekly insecticide spray including labour charge by using this method a farmer will save minimum of 1 lakh Rs/- per hectare with increase in crop yield (The Hindu article- IIHR Entomology Division Bengaluru).

7.5 Effect of synthetic molecules against brinjal shoot and fruit borer:

Farmers rely exclusively on the use of synthetic insecticides in order to combat the pest (69) reported that farmers apply insecticides 10-12 times in winter and 25-30 times or even more in summer or rainy season. This is due to the increase in activity of *L. orbonalis* during warm and humid season. The trend of using insecticides with can cause development of pest resistance and environmental contamination**.** However, insecticides are the only measures practiced to control this pest in commercial cultivation of Brinjal.

Many workers have reported the efficacy of insecticides in controlling the fruit and shoot borer of Brinjal throughout the world. Spinosad, Fenvalerate, Emamectin Benzoate, Chlorpyriphos, Cypermethrin, Carbofuran, Carbosulfan, Aldicarb granules, Phorate, Dimethoate, Carbaryl, Malathion etc are frequently used as control measures and sprayed in different concentration and combinations. Azadirachtin 0.003% EC (Multi neem, Nimbecidine), Emamectin benzoate 5% SG, Cypermethrin 25% EC and Fenvalerate 20% EC have been recommended against this pest (Krishi Diary, MOA). The experiments using chemical pesticides revealed the effectiveness of Flubendiamide, Spinosad and Chlorfenapyr against L. orbonalis respectively in reducing the infestation on eggplant and it eventually led to increase in yield. Similarly, the overall damage caused by the pest was also reduced by the application of Emamectin Benzoate, Methoxyfenozide and *Bacillus thuringiensis* along with increment in the yield of Brinjal (69). Three sprays of Chlorpyriphos + Cypermethrin @ 0.01 percent a.i. in 15 days intervals resulted in minimum shoot infestation of 2.15% and 12.95% fruit infestation. It was followed by alphamathrin @ 0.01 percent and the highest marketable yield of 87.77q/ ha was also obtained from application of alphamathrin. (69), suggested that the combination of Chlorpyriphos 50% EC + Cypermethrin 5% EC can be utilized as a valuable chemical component in Integrated Pest Management for *L. orbonalis* in eggplant crop. Emamectin Benzoate (0.002%) and Endosulfan (0.05%) demonstrated superior results in terms of reduction of infestation of shoot and fruit in Brinjal followed by Novaluron in case of shoot infestation (7.00) Sharma and Sharma (2010) [7, 28]. According to (69), the pest population was suppressed when Emamectin benzoate was applied and lowest mean percent of fruit infestation 40.1% was recorded after its application. It was followed by Cypermethrin with 40.43% fruit infestation (69,71), found that Tracer-45 SC(Spinosad), Bactoil, Proclaim-5 SG demonstrated significantly higher mortality against 4th instar larvae of BSFB while (69,71) reported from his experiment that Chlorantraniliprole is the best insecticides among treatments for effective management of Brinjal shoot and fruit borer followed by Spinosad. Similarly, the fruit infestation by number basis revealed that the treatment Chlorantraniliprole excelled all other treatments; the other best treatment Spinosad was at par difference with it; on weight basis, the Chlorantraniliprole and Spinosad significantly effective insecticides are Chlorantraniliprole, Emamectin benzoate, Spinosad followed by other insecticides. Although the use of these insecticides excelled other methods of control, these insecticides left some unwanted negative effects leading to the reduction of natural enemies of *L. orbonalis*, increased pest resistance and resurgence, environmental pollution and severe impacts on human health. There could be chemical residue after the use of chemical pesticides in an unsafe manner as such residue of Malathion, Parathion, Fenitrothion 0.64, 0.36 and 0.64 ppm respectively was found in fresh Brinjal sale in the market (69). Similarly, many people also died in Nepal recently due to Excessive Chemical pesticides in vegetables. Thus, the use of insecticides should be followed with extreme precautions and only if other methods become ineffective in controlling the pest. However, chemical pesticides along with IPM practices can prove to be very effective than using any methods alone.

7.7 Integrated pest management approaches for BSFR

IPM is the integrated practice method which includes all of the methods to control the pest. For *L. orbonalis*, no single practice can be considered effective and thus only integrated management can bring effective result in its control and management. Successful adoption of IPM in Brinjal cultivation can ensure sustainable cultivation practice and helps in preservation of environment and less negative impacts on human health. It includes the use of sex pheromones, physical and mechanical barriers, pruning and pinching practices, bio-control and bio-pesticides and other chemical insecticides for effective control and management of pest. (69,71), demonstrated the efficient model of IPM strategy based on the yield performance. According to him, the efficacy of first one is the highest and lowers on later. The most effective models of IPM as per him are:

- Flubendiamide together with NSKE, NLE, Deltamethrin + Trizophos
- Application of new molecule of Rynaxypyr, NLE, NSKE, Chlorpyriphos
- NSKE, *Emamectin Benzoate*, NLE, Chlorpyriphos, Neem and Oil.

The fruit damage was significantly reduced when coriander intercropping was practiced in eggplant (antifeedant) (69,71). It was also found that integration of phyto sanitation, application of Neem Seed Kernel Extract (NSKE) and mechanical control had significant impact on the incidence and damage of BFSB (69,71). The IPM treatment involved withholding of all pesticide use, weekly clipping of damaged shoots, and installation of sex pheromone for mass trapping of male adults showed that the fruit infestation in IPM plots was much less in pesticide spray (check) plots (69,71), reported that the combined treatment including pesticides, botanicals and cultural methods resulted lower shoot and fruit damage as well as the fruit yield was also increased. Similarly, the module with three different component as per Dutta., *et al*. (2011) [20], *viz*. pheromone trap, mechanical control and application of Peak Neem (neem based insecticide) was the best and reduced the shoot damage, fruit damage and also increased the yield. Endosulfan + Deltamethrin (0.07%, 0.0025%) and Endosulfan + Fenvalerate (0.07% + 0.005%) were highly effective against BFSB and 13.3% damage was recorded while 69.8% damage was seen in control (69,71). The use of chemical pesticides in

IPM was not practiced initially but the judicious use of pesticide was accepted globally. IPM includes combination of different management practices and it is proved that combined tactics are far more effective than single measure against the pests. However, one must consider the compatibility and cost benefit ratio of these practices when applying for commercial cultivation.

Fig 1: Adult of BSFB

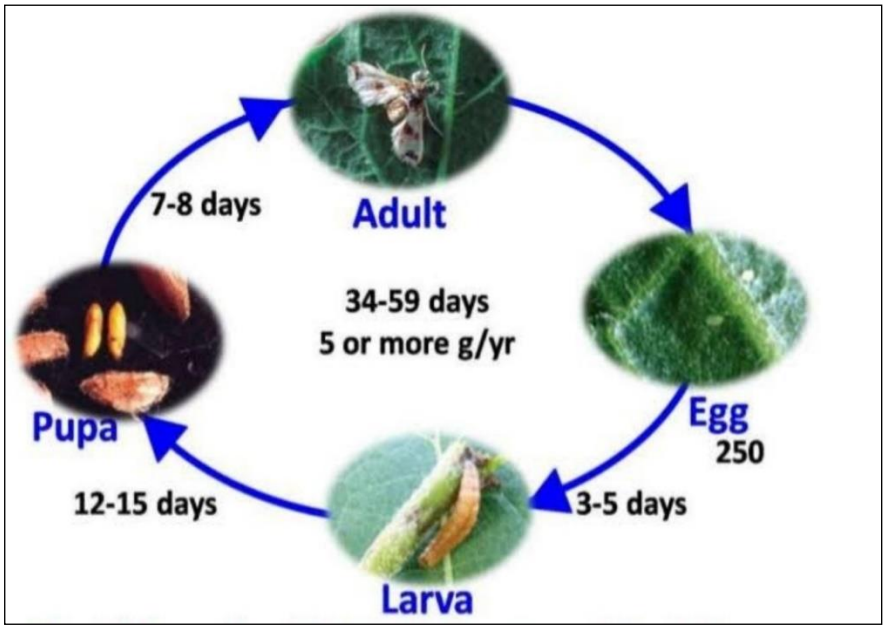

Fig 2: Life cycle of BSFB

Table 1: Bioagent of Brinjal shoot and fruit borer, *Leucinodes orbonalis*

Natural enemy species	Family and Order	Country	Reference (71)
Predators			
Chrysopa kulingensis	Chrysopidae, Neuroptera	China	
Campyloneura sp	Miridae, Heteroptera	India	
Cheilomenes sexmaculata Coccinella septempunctata Brumoides suturalis	Coccinellidae, Coleoptera	India	
Parasitoid			
Pseudoperichaeta sp	Tachinidae, Diptera	India	
Phanerotoma sp	Braconidae, Hymenoptera	India, Sri Lanka	
Apanteles sp	Braconidae, Hymenoptera	Philippines	
Chelonus sp	Braconidae, Hymenoptera	Philippines, Sri Lanka	
Brachymeria lasus	Chalcididae, Hymenoptera	Philippines	
Dermatopelte sp	Eulophidae, Hymenoptera	China	
Trathala flavoorbitalis	Ichneumonidae, Hymenoptera	Bangladesh, India, Malaysia,	

		Philippines, Sri Lanka	
Cremastus hapaliae	Ichneumonidae, ymenoptera	Malaysia	
Xanthopimpla punctata	Ichneumonidae, ymenoptera	Philippines	
Itamoplex sp	Ichneumonidae, ymenoptera	India	
Eriborus argenteopilosus	Ichneumonidae, ymenoptera	India	
Diadegma apostata	Ichneumonidae, ymenoptera	India	
Entomopathogens			
Bacterium		China	
Fungus (Bipolaris tetramera)		India	
Baculovirus		India	
Nuclear polyhedrosis virus		India	

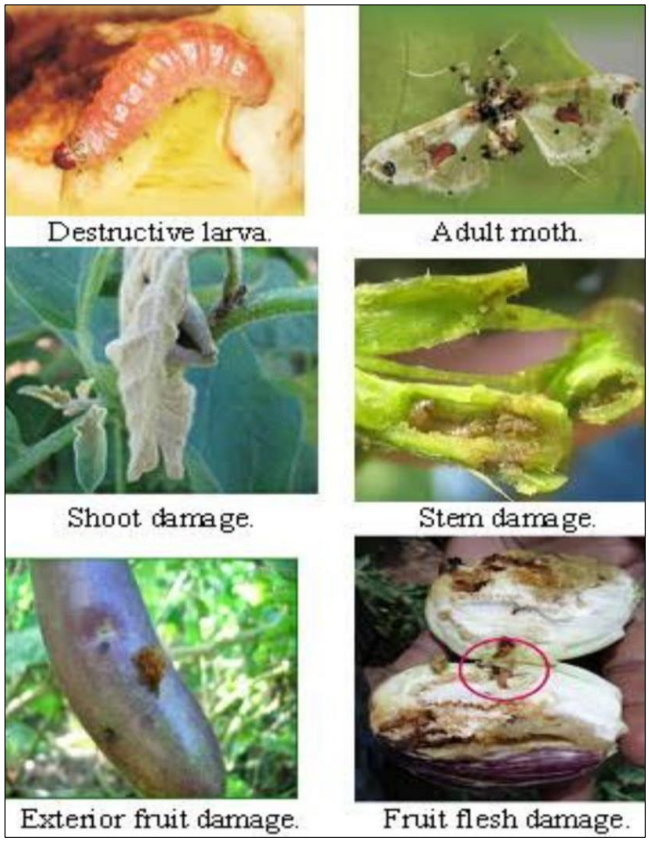

Fig 3: Nature of Damage of BSFB

8. Conclusion

BSFB it is a oligophagous pest mainly feeds on brinjal and also on other vegetables belongs to Solanaceae family. Because of its short life cycle and boring nature leads to declining in the growth and development of brinjal crop and also because of this key pest farmers seeing a huge losses. To control this key pest farmers are using insecticides in indiscriminate and injudicious way leads to residual effect on human beings cause resurgence of pest, harm the environment, also destroys the natural enemies population in the field. Due to this negative impact of insecticides to control BSFB instead of this to save the environment and the population of natural enemies using of bio control agents to control BSFB is the ideal way. Because the biological control agents are safe to environment and does not affect human consumption and it is a pure eco-friendly approach.

9. Future aspects

To save the environment and natural enemies population use biological control agents instead of using insecticides.

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