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Review Article

Biology and Management of Eggplant (*Solanum melongena* L.) Shoot and Fruit Borer: A Review

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Abstract

Eggplant (*Solanum melongena* Linnaeus) is a vital crop in South Asia, valued for its use in both raw and cooked dishes. However, its cultivation is severely threatened by the eggplant shoot and fruit borer, *Leucinodes orbonalis* (Guen.), which damages the plant from the seedling stage to harvest. The larval phase of this pest bores into shoots and fruits, potentially causing up to 90% loss and a decline in quality. Farmers often use excessive insecticides to combat *L. orbonalis*, leading to residue accumulation in food, insecticide resistance, pest resurgence, secondary pest outbreaks, and harm to beneficial organisms and the environment. In South Asia, this pest is the primary threat to eggplant fields, attracting significant research attention. This review paper examines biology, damage and control measures of eggplant shoot and fruit borer including resistant and tolerant varieties, sex pheromone traps, physical and mechanical barriers, biopesticides, biocontrol agents, and cultural and chemical methods, supported by previous studies and research findings.

Introduction

Brinjal or eggplant (*S. melongena* Linn.) is a solanaceous vegetable crop known for high yields in the hot-wet climates of South and Southeast Asia (Niranjan et al., 2017; Thapa, 2010; Hanson et al., 2006). Although primarily a summer crop, it can be grown up to three times a year with adequate irrigation. About 85% of the world's eggplant production occurs in China, India, Bangladesh, Nepal, and Sri Lanka (FAO, 2021).

Eggplant cultivation has become costly and hazardous due to rising production costs from combating insect pests with chemical pesticides (Alam et al., 2006). Eggplant is susceptible to many insect pests, including the eggplant shoot and fruit borer, epilachna beetle, aphid, jassid, leaf roller, leaf hopper, hairy caterpillar, mealy bug, whitefly, and spider mites, affecting the plant from seedling to fruiting stages (Regupathy et al., 1997; Thapa, 2010). Among these, the eggplant shoot and fruit borer (ESFB), *L. orbonalis* Guenee, is the most notorious and destructive pest, prevalent in all brinjal-producing countries (Latif et al., 2010; Dutta et al., 2011).

ESFB caterpillars can cause wilting and drying of stems by burrowing into the petiole and midrib of leaves and tender shoots (Saraswathi et al., 2022). ESFB causes severe economic damage by creating holes and tunnels in the fruit, leading to flower drop and deformities. Infested fruits are unsuitable for consumption due to larval excrement, with infestation rates reaching up to 90.86% (Prodhan et al., 2018; Baral et al., 2006; Rahman, 1997).To fight against *L. Orbonalis*, almost 98% of Bengali farmers solely depend on insecticides (Karim, 2004). However, widespread chemical use has led to resistance, pest resurgence, secondary pest outbreaks, toxic residue accumulation, and ecological imbalance (Ahmad et al., 2008). To mitigate economic damage caused by *L. Orbonalis*, management is a crucial agricultural practice. Thus, finding alternative and safer solutions is imperative.

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Methods

This paper gathers necessary information through a thorough examination of journal articles, research proceedings, theses, annual reports, survey reports, reviews, and library resources, focusing on eggplant shoot and fruit borer pest management strategies. By critically analyzing existing literature, systematically summarizing information, and providing conclusive insights, we aim to enhance understanding of ESFB control methods and suggest directions for future research.

Biology

ESFB is monophagous, feeding mainly on eggplant; though, other plants such as potato, sweet potato, tomato, winter pea, turkey berry, gilo, and black nightshade are found to be hosts of this pest (CABI, 2007). The larval stage is the most extended (Fig. 1), followed by the pupal stage and the incubation period (Abhishek and Dwivedi, 2021; Mainali, 2014).

Egg

Typically, oviposition by eggplant shoot and fruit borers occurs at night, with females laying eggs 2 to 5 days after mating. Eggs are deposited individually or in clusters, numbering between 52 to 250 per female, on the undersides of leaves, calyxes of fruits, green stems, or flower buds (Alam et al., 2003; Iesa, 2021). Clusters of eggs can also be found on the ventral surface of leaves, sometimes reaching up to 260 in number, during early morning hours (Mainali, 2014; CABI, 2007; FAO, 2003). The eggs are initially creamy-white, becoming red before hatching. Hatching occurs within 3 to 5 days in summer and 7 to 8 days in winter, yielding dark white larvae (Mainali, 2014; Rahman, 2006).

Larvae

After hatching, young caterpillars quickly burrow into petioles, tender shoots, and midribs of large leaves for nourishment during the vegetative stage. As plants mature into the reproductive phase, larvae feed on flower buds and fruits (Showket et al., 2017; Abhishek and Dwivedi, 2021). Larvae typically undergo 5 to 6 instars and take 12–15 days in summer and 14-22 days in winter to develop (Rahman, 2006; Atwal, 1976; Baang and Corey, 1991). During this period, larvae hide within shoots or fruits, protecting themselves from predators and environmental stress such as rainfall and strong wind (Alam et al., 2006). Larval feeding causes significant damage to eggplant production, with a single fruit potentially hosting up to 20 larvae (Mainali, 2014; Shaukat et al., 2018; Frempong, 1979).

Pupa

The pupal stage of the eggplant shoot and fruit borer lasts 6 to 17 days, depending on the temperature (Alam et al., 2006). In summer, it lasts about 7-10 days, while in winter, it extends to 13-15 days (Alam et al., 2003; Rahman, 2006). Mature larvae leave the infested shoots and fruits to pupate within sturdy silken cocoons found in dried shoots and leaves, plant debris on the ground, or the soil surface near the host plant (Alam et al., 2003; Mainali, 2014). The cocoons blend with their surroundings, making them difficult to detect and protecting them from predators and other threats (Alam et al., 2006).

Adult

The small white adult moths of the eggplant shoot and fruit borer emerge from pupal cocoons mostly at night and are found under leaf surfaces or within the plant canopy (Mainali, 2014; Saxena, 1965; Showket et al., 2017). Key behaviors such as feeding, mating, and egg-laying occur primarily at night (Mainali, 2014). Females, larger than males with a broader wingspan, typically mate at night or early morning (Jat et al., 2003; Raina and Yadav, 2017). The adult moths mature in 10 to 14 days, completing their life cycle in 22 to 55 days. After mating and laying eggs, adult males and females die, respectively (Mehto et al., 1983; Kar and Khan, 1995). ESFB produces five generations annually, being more active in the summer and rainy seasons, and less active in winter. Higher temperatures and lower humidity increase fecundity and shorten the life cycle duration of ESFB (Mainali, 2014).

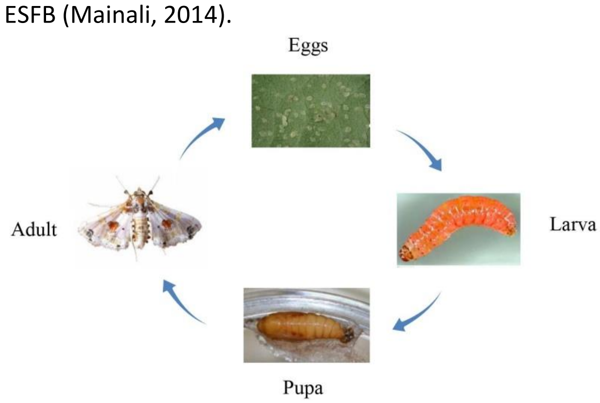

Fig. 1. Life stages of eggplant fruit and shoot borer

Nature of damage

Though ESFB is active year-round in moderate climates, its damage is particularly severe in autumn, potentially devastating the crop (Atwal, 1976). Shortly after hatching, the larva infiltrates the nearest eggplant fruit, tender shoot, or flower, sealing the entry hole with black excreta and remaining hidden (Alam et al., 2003). Larval feeding renders the fruit unmarketable, with a single larva capable of damaging 4-6 healthy fruits

(Alam et al., 2006; Dar and Mir, 2016; Pandey et al., 2016; Anonymous, 2010). Caterpillars cause wilting, dropping, and withering of tender shoots, leading to delayed crop maturity, stunted growth, and reduced fruit number and size (Butani and Jotwani, 1984; Alpuerto, 1994; AVRDC, 1999). Larval feeding on flowers decreases fruit numbers and lowers production (AVRDC, 1999). Secondary fungal infestation further reduce fruit quality (Islam and Karim, 1994).

Management approaches

Various management approaches can be taken to effectively control ESFB pests (Fig. 2).

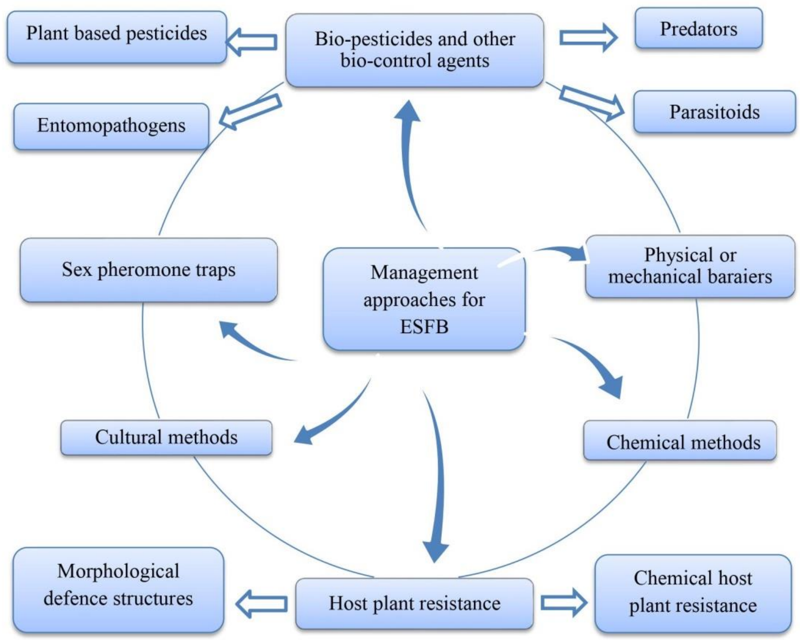

Fig. 2. Management approaches for eggplant shoot and fruit borer

Sampling or scouting procedures

To effectively manage current pest outbreaks and anticipate future ones, it is crucial to implement early intervention and establish economic thresholds. Scouting, including methods like visual search, sweeping net, and pitfall traps (Awal et al., 2015), is the initial step in controlling insect pests and estimating ESFB numbers in brinjal fields. To limit adult movement, a morning visual inspection of the lower leaf surface is conducted. The sweeping net method assesses insect abundance, and the pitfall trap method captures roaming insects on the soil surface (Akter et al., 2018).

Host plant resistance

Plants and insects have been living together and interacting for over 350 million years (Whitney et al., 2013). During this time, plants evolved constitutive and inducible defenses to minimize insect damage, leading to host plant resistance (Mouden et al., 2017). Resistant and tolerant varieties are considered the primary defense against ESFB, as these varieties often exhibit reduced fruit infestation (Lit, 2009). These resistant varieties (Table 1) possess physical, biochemical, or morphological traits that diminish the plant's suitability or attractiveness for pests to feed on, develop, or reproduce successfully (Verma et al., 2020).

Morphological defense structures

Resistant eggplant varieties (Table 1) typically feature thicker and elongated clasping calyxes that cover a significant portion of the fruits, making it challenging for larvae to penetrate and bore into them (Dar et al., 2017). Eggplants with narrow and elongated fruits containing long hairs are observed to experience lower infestation rates due to the reduced preference of pests for egg-laying compared to plants with wide and short fruits (Gautam et al., 2019). Pericarp thickness is significantly positively correlated with brinjal fruit infestation, while trichome density is significantly negatively correlated (Challa et al., 2021).

Chemical host plant resistance

Plant chemical defenses originate from primary and secondary metabolites. Previous studies have reported negative correlation between total phenols, polyphenol oxidase, peroxidases, phenylalanine ammonium lyase, and solasodine contents in eggplants and percent fruit infestation by *L. orbonalis,* while reducing and non-reducing sugars were positively correlated. Resistant genotypes accumulated higher levels of defensive enzymes including phenols, PO, PPO, PAL, and solasodine to provide insect resistance (Challa et al., 2021).

Table 1. Eggplant resistant and tolerant varieties to shoot and fruit borer *L. orbonalis*

Location	Resistant and tolerant genotype(s)	Reference
India	Swarna, Shyamli, Green long-183, Utsav and Navkiran	(Supriya and Singh 2019)
	Pant Samrat	(Choudhary et al., 2018)
	12/SPT BL VAR 7 and Punjab Sadabahar	(Netam et al., 2018)
	Ganesh and DS-407	(Sharma et al., 2017)
	IGB-92	(Patel et al., 2015)
	Navkiran and Pusa Purple Long - 74	(Mathur et al., 2012)
	Hybrid Turbo, ISD 006, BL009, and EG058,	(Srinivasan 2008)
	Bhagyamathi, Singhnath, Pusa Purple Cluster, and Nurki, Annamalai,	(Behera et al., 1999)
	Brinjal Long Green, Chikon Long, Arka Kusumakar, Arka Shirish, Nischintapur, Altapati, Manjpur, and Makra	(Gangopadhyay et al., 1996)
	Pusa Purple Cluster, , Doli-5, Chaklasi Doli, and Junagarh Long	(Jyani et al., 1995)
	Long Purple	(Mehto et al. 1983)
Bangladesh	Marich begun S and Katabegun WS	(Ahmad et al., 2008)
	EG075	(Cork et al., 2003)
	Singhnath long, Singhnath-4, Jumki-1, Jumki-2, Islampuri-3, and BL-34	(Mannan et al., 2003)
Philiphines	EG203	(Lit, 2009)
Nepal	Pusa Purple Long, Neelam Long, Nurki, and Pusa Kranti	(Thapa et al., 2009) and (NARC, 1998)
Pakistan	Hybrid 3715, Nirala, and Shilpa	(Yousafi et al., 2016)

Sex pheromone traps

Sex pheromone traps play a crucial role in Integrated Pest Management (IPM) programs for controlling ESFB (Alam et al., 2003). Sex pheromones attract and reduce adult males of *L. Orbonalis*, decrease misuse of insecticide, and enhance the activity of natural enemies (Mathur et al., 2012, Srinivasan, 2012). E-11-hexadecenyl acetate (E11-16: Ac) is the most usual BFSB sex pheromone component identified and synthesized in laboratory. A high concentration of E11-16: Ac alone or a low dose combination of E11-16: Ac and E11-16: OH (in ratios of 10:0.5 or 10:1) in pheromone-baited traps can effectively attract large numbers of male moths (Srinivasan and Babu, 2000). However, trap design, placement, and elevation significantly affect their effectiveness. Delta and wing traps lured with synthetic *L. orbonalis* female sex pheromones were found to be ten times more effective at capturing moths than spodoptera or uni-trap designs (Cork et al., 2003). Traps should be spaced 10-15 meters apart and positioned so that the lure is placed just above the plant canopy (Showket et al., 2017). Optimal pheromone baits should consistently release sufficient pheromones to attract the maximum number of male moths (AVRDC, 1999a). Using pheromone traps from 15 days after transplanting until harvest, with monthly bait changes, maximized protection against fruit damage (38.17%), shoot damage (58.39%), and increased production (49.71%) compared to control methods (Dutta et al., 2011).

Cultural methods

The timing of eggplant planting is crucial for ESFB yield, as factors like temperature, humidity, sunlight, precipitation, and wind, have impacted on shoot and fruit borer populations. Dhawan et al. (2013) recommended transplanting brinjal plants either in early March-April or late July to optimize growth and minimize pest infestations. Pruning should start early in crop growth and continue until the final harvest, involving the removal of infested twigs and branches, eliminating unwanted, infested, and withered plants, and reducing dense populations to prevent the spread of *L. orbonalis* (Neupane, 2000; Singh and Nath, 2010). Larvae usually feed within tender shoots before fruiting, but once fruiting starts, they prefer entering fruits. Thus, regularly removing infested eggplant shoots and fruits while leaving healthy ones undisturbed is advisable (Srinivasan, 2008). Removing alternate hosts such as tomato, potato, chili, and other crops from the Solanaceae family near the brinjal field is essential as they can provide shelter and favorable conditions for *L. orbonalis* (Murthy and Nandihalli, 2003). High plant nitrogen levels can worsen insect infestations, while low potassium levels trigger the synthesis of jasmonic acid, boosting the plant's resistance to insect pests and some diseases (Hodson and Lampinen, 2018; Davis et al., 2018). Several bird species, such as myna, king crow, common weaver bird, house sparrow, common bee eater, black drongo, black rock pigeon, bulbul, tailorbird, hoopoes, flycatcher, and fowl turkey, are known insectivores. Installing bird perches in the field offers resting spots for these predatory birds, which actively hunt for prey (David and Ananthakrishan, 2004; Rao et al., 2002).

Physical or mechanical barriers

Installing nylon net barriers at appropriate heights can effectively protect eggplants by blocking adult moths' access, as moths typically have limited flying abilities and tend to travel short distances between plants or plots (NARC, 2000). Alam et al. (2003) discovered that employing mechanical barriers alongside promptly removing pest-damaged shoots can decrease shoot damage by an average of 62.7%. Cultivating eggplant in net or poly houses is common worldwide. Varieties such as BH-1, BH-2, and Punjab Barsati produce significantly higher marketable yields compared to other varieties grown in net houses (Kaur et al., 1998). Thus, using mechanical barriers is a promising strategy to mitigate *L. orbonalis*. However, the economic feasibility of net barriers or net houses must be considered.

Biopesticides and other biocontrol agents

Biological control entails releasing natural enemies of insects in higher numbers and employing conservation strategies to maintain their abundance and effectiveness. Several well-known biocontrol agents, such as predators, parasitoids, bacteria, viruses, and fungi, have been documented to act against *L. orbonalis* (Table 2).

Predators

In the absence of chemical insecticides, predators can control populations of ESFB to non-economically damaging levels (Kafle, 1970). In 2019, Borkakati et al. identified four key predators of insect pests on brinjal: the coccinellid beetle, the syrphid fly (*Episyrphus balteatus* De Geer), the green lacewing (*Chrysoperla carnea* Stephens), and spiders from the *Oxyopes* genus.

Parasitoids

Many parasitoids have been identified worldwide as biocontrol agents of ESFB *Leucinodes orbonalis* (Table 2) (Srinivasan, 2008). Among these biocontrol agents, *Trichogramma chilonis* Ishii has been shown to be the most effective parasitoid, specifically targeting the egg stage of the pest (Jyoti and Yadav, 2018).

Entomopathogens

Entomopathogenic fungi such as *B. bassiana* and *B. tetramera*, along with Nuclear Polyhedrosis Viruses (NPV), have demonstrated effectiveness in reducing shoot infestations and improving the marketable production of brinjal (Whitten and Oakeshott, 1991; Mathur et al., 2012; Gupta and Rosan, 1995).

Bacillus spp. bacteria are key players in ESFB control, with *Bacillus thuringiensis* (Bt) being the most commonly used microbial agent for managing insect pest infestations and improving brinjal yields (Chatterjee and Mondal, 2012). Although Bt-based insecticides account for only about 4% of the global pesticide market, they are crucial for integrated pest management (IPM) strategies due to their minimal impact on non-target organisms (Srinivasan, 2012).

Spinosad combined with infested shoot and fruit removal, and emamectin benzoate combined with buprofezin, are recommended for sustainable ESFB management (Sarker et al., 2020). Singh et al., (2021) found that spinosad 45SC at 0.5 ml L^{-1} was most effective, resulting in the lowest shoot damage (2.03% and 2.0%) and fruit damage (12.66% and 10.62%), and the highest yields (25.39 t ha^{-1} and 26.99 t ha^{-1}) during the 2015-2016 and 2016-2017 seasons. They also suggested using spinosad 45SC at 0.5 ml/l, chlorantraniliprole 20SC at 0.4 ml/l, and emamectin benzoate 5SG at 0.5 g/l, either individually or in rotation, to manage brinjal shoot and fruit borers.

Table 2. Natural enemies of EFSB in South and Southeast Asia

Natural enemy species	Order	Family	Reference
	Predators		
Coccinella transversalis (Fab.)	Coleoptera	Coccinellidae	
Harmonia dimidiata (Fab.)	Coleoptera	Coccinellidae	
Adalia bipunctata (L.)	Coleoptera	Coccinellidae	
Cheilomenes propinquq (Muls.)	Coleoptera	Coccinellidae	(Borkakati et al., 2019)
Brumoides sp. (Fab.)	Coleoptera	Coccinellidae	
Episyrphus balteatus (De Geer)	Diptera	Syrphidae	
Chrysoperla carnea (Stephens)	Neuroptera	Chrysopidae	
Oxyopes sp.	Araneae	Oxyopidae	
Chrysopa kulingensis	Neuroptera	Chrysopidae	(Yang, 1982)
Campyloneura sp	Heteroptera	Miridae	(Tripathi and Singh, 1991)
Cheilomenes sexmaculata	Coleoptera	Coccinellidae	(Kadam et al., 2006)
Coccinella septempunctata	Coleoptera	Coccinellidae	
	Parasitoids		
Pseudoperichaeta sp	Diptera	Tachinidae	(Patel et al., 1971)

Natural enemy species	Order	Family	Reference
Phanerotoma sp	Hymenoptera	Braconidae	
Apanteles sp	Hymenoptera	Braconidae	
Chelonus sp	Hymenoptera	Braconidae	
Brachymeria lasus	Hymenoptera	Braconidae	(Navasero, 1983)
Xanthopimpla punctata	Hymenoptera	Ichneumonidae	
Dermatopelte sp	Hymenoptera	Eulophidae	(Yang, 1982)
Trathala flavoorbitalis,	Hymenoptera	Ichneumonidae	(Yunus and Ho, 1980)
Cremastus hapaliae	Hymenoptera	Ichneumonidae	
Itamoplex sp	Hymenoptera	Ichneumonidae	(Verma and Lal, 1985)
Eriborus argenteopilosus	Hymenoptera	Ichneumonidae	(Tewari and Sardana, 1987)
Diadegma apostata	Hymenoptera	Ichneumonidae	(Krishnamoorthy and Mani, 1998)
Trichogramma chilonis	Hymenoptera	Trichogrammatidae	(Jyoti and Yadav, 2018)
Pathogens			
Fungi			
Metarhizium anisopliae	Hypocreales	Clavicipitaceae	(Tripathi and Singh, 1991)
Beauveria bassiana	Hypocreales	Cordycipitaceae	
Lecanicelium lecanii	Hypocreales	Cordycipitaceae	
Nomuraea rileyi	Hypocreales	Clavicipitaceae	
Hirsutella thompsonii	Hypocreales	Ophiocordycipitaceae	
Bipolaris tetramera	Pleosporales	Pleosporaceae	
Paecilomyces fumosoroseus	Hypocreales	Cordycipitaceae	
Bacteria			
Bacillus thuringiensis	Bacillales	Bacillaceae	(Chatterjee and Mondal, 2012)
Virus			
Nuclear Polyhedrosis Virus			Gupta and Rosan, 1995

Plant based pesticides

Botanical insecticides (Table 3) are more beneficial than chemical or synthetic ones because they are less harmful to non-target organisms, less likely to cause resistance, and biodegradable (Siam et al., 2021). Utilizing botanicals and biopesticides is preferred over conventional insecticides, especially as they integrate well within integrated pest management (IPM) strategies (Srinivasan, 2008; Mathur et al., 2012; Prakash et al., 2008). Azadirachtin, found in neem seed extracts, shows antifeedant and sterilizing effects on ESFB (Saimandir and Gopal, 2012). Oils from iluppai and pungam plants, and their combination (pungam oil 1% + iluppai oil 1%), have been effective against ESFB (Ndereyimana et al., 2013). Although classified as biopesticides, extracts like pyrethrins and azadirachtin, as well as microbial extracts like avermectin and spinosad, contain chemical compounds that pose safety risks to humans and the environment similar to synthetic chemicals (Sarfraz et al., 2005).

Table 3. Plant extracts that showed the reduction of shoot and fruit borer infestation in eggplant

Plant extracts	Action	References
Neem oil @ 2%	Killing effect	(Chiga et al., 2019)
sweet flag concentration and ash powder	antioviposition effects	(Ranjith et al., 2019)
Chili and Lantana	Antifeedent	(Duza et al., 2019)
Neem oil @ 0.3% and Iluppai (Madhuca indica Gmelin) and NSKE @ 5%; 2% botanical oils of Pungam (Pongamia pinnata Linnaeus)	Effective in suppressing population	(Mathur et al., 2012)
Alata soap @ 5 g/litre of water; Ecogold @ 10 ml/litre of water; Neem oil @ 3 ml/l of water); Garlic @ 30 g/litre of water; Papaya leaves @ 92 g/litre of water and wood ash @ 10 g/plant and neem leaf extract @50 g/L	Killing effect	(Mochiah et al., 2011)
Neem, *Azadirachtin indica,* Neem tablet at 1:4 (w/v) concentration; garlic, allamanda, neem, garlic+neem and allamanda+neem tablets	Chitin synthesis inhibitor (CSI) and killing effect	(Moniruzzaman et al., 2010)
Neem derivatives	Repellent, antifeedants and act as deterrents	(Atwal and Dhaliwal, 2008)
NSKE and dried powder of Acorus calamus and sweet flag concentration	63% ovicidal action	(Yasodha and Natarajan, 2007)

Chemical methods

Because of their immediate action against ESFB chemical pesticides have always been considered as the go-to-solution for the farming community (Kumar et al., 2020). In winter, farmers use insecticides 10-12 times, but in the warmer, more humid summer months, they increase usage to 25-30 times or more due to heightened *L. orbonalis* activity (Ghimire, 2001). To avoid resistance and stop secondary pest's outbreak and resurgence, insecticides of the same group should not be used repeatedly. A waiting period of seven days should be maintained after each spray (Atwal and Dhaliwal, 2010). Farmers depend on chemical insecticides throughout the entire eggplant cultivation process, from field preparation and seed sowing to harvesting and marketing. There are a large number of insecticides from different groups that are effectively used in ESFB pest management (Table 4). Although insecticides are effective against ESFB, they come with disadvantages such as harming natural enemies of *L. orbonalis*, promoting pest resistance, contributing to environmental pollution, and posing health risks. Improper use can also result in chemical residues in brinjal. Thapa (1997) detected residues of Malathion, Parathion, and Fenitrothion in fresh brinjal at concentrations of 0.64 ppm, 0.36 ppm, and 0.64 ppm, respectively.

Table 4. Effect of test insecticides against *Leucinodes orbonalis* Guen. on shoot infestation

Chemicals name and formulation	Group	Dose	Mean infestation (%)	Reference
Lambda-cyhalothrin (Cyclone 2.5 EC)	Synthetic pyrethroid	1.5 (ml L^{-1} water)	16.45	(Rahman et al., 2019)
Lufenuron (Heron 5 EC)	Insect Growth regulator	1.0 (ml L^{-1} water)	14.51	
Chlorpyrifos (Lorsban 40 EC)	Organophosphate	2.0 (ml L^{-1} water)	9.34	
Methamidophos (Tamaron 600 SL)	Organophosphate	1.5 (ml L^{-1} water)	9.23	
Endosulphan (Thiodan 35 EC)	Cyclodiene	2.0 (ml L^{-1} water)	15.96	(Ali et al., 2016)
Imidacloprid (Confidor SL 20)	Neonicotinoids	0.5 (ml L^{-1} water)	12.37	
Cypermethrin (Ripcord 100 g/l EC)	Synthetic pyrethroid	2.0 (ml L^{-1} water)	11.44	
Flubendiamide 20 WG	pthalmic acid diamides	30 (g a.i. ha^{-1})	2.65	
Chlorantraniliprole 18.5 SC	anthranilic diamides	27.75 (g a.i. ha^{-1})	2.77	
Flubendiamide 20 WG	pthalmic acid diamides	20 (g a.i. ha^{-1})	3.43	
Chlorantraniliprole 18.5 SC	anthranilic diamides	18.5 (g a.i. ha^{-1})	3.76	(Mahata et al., 2014)
Indoxacarb 14.5 SC	non-systemic insecticide	72.5 (g a.i. ha^{-1})	3.96	
Novaluron 10 EC	insect growth regulators	62.5 (g a.i. ha^{-1})	4.34	
Flubendiamide 20 WG + Thiamethoxam 25 WG	pthalmic acid diamides + neonicotinoids	15 + 31.25 (g a.i. ha^{-1})	5.25	
Thiamethoxam 25 WG	neonicotinoids	62.5 (g a.i. ha^{-1})	6.62	
Cartap (Suntap 50SP)	Carbamate	1.0 (g L^{-1}water)	3.82	
Carbosulfan (Marshal 20EC)	Carbamate	3.0 (ml L^{-1} water)	1.33	(Latif et al., 2010)
Thiodicarb (Larvin 75WP)	Carbamate	1.0 (g L^{-1}water)	4.60	

Conclusion

The monophagous primary pest of brinjal, *Leucinodes orbonalis* Guenee, is prevalent throughout tropical regions but poses the greatest threat in Southeast Asian brinjal fields, ranking as the most significant menace. Its short life cycle and burrowing behavior exacerbate its impact in this area. Farmers combat this major pest by excessively and indiscriminately employing chemical insecticides, resulting in residue accumulation in the food chain, pest resurgence, secondary pest outbreaks, environmental harm, and the depletion of natural enemy populations and non-target organisms. While resistant varieties are the preferred initial defense against ESFB, no such varieties have yet been developed to adequately withstand the pest. An eco-friendly approach to managing the brinjal shoot and fruit borer involves combining methods such as sex pheromone traps, physical or mechanical barriers, biopesticides, biocontrol agents, cultural practices, and judicious chemical interventions.

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