Introduction to Insect Pests of Brinjal (*Solanum melongena* L.) and Their Management: A Review

Comment [i1]: Suggest the following title ((Overview of Brinjal (Solanummelongena L.) pests and their management: A review)).

Abstract

Brinjal (eggplant or aubergine), a widely cultivated vegetable in tropical and subtropical regions, faces significant threats from a variety of insect pests. These pests cause substantial damage at different stages of crop growth, leading to reduced yields and compromised fruit quality. This review provides a comprehensive overview of the major insect pests that affect brinjal cultivation, focusing on their biology, damage mechanisms, and current management practices. Special emphasis is placed on integrated pest management (IPM) strategies, combining chemical, biological and cultural control methods to promote sustainable brinjal production.

Keywords: Damage mechanism, current management practices, IPM and insect pests.

Comment [i2]: Words (Brinjal , Solanummelongena L.) can also be added here.

1. Introduction

Brinjal (*Solanum melongena*), an important solanaceous crop, is widely grown in Asia, Africa, and the Mediterranean region. It serves as a significant dietary source of vitamins, minerals, and antioxidants, and contributes to the livelihoods of smallholder farmers. However, brinjal is susceptible to a wide range of insect pests, which can result in heavy economic losses due to their detrimental effects on plant health and fruit quality. Effective pest management is therefore essential for sustaining high yields and ensuring profitability for farmers. This review aims to present an overview of the primary insect pests of brinjal and the strategies employed for their management. The managing pests population of *Solanum melongena* different methods have been used, but to keep the population below the economic injury level chemical control is one of the common practices, many of the insecticides applied are not effective in the satisfactory control of these pest (Sahu *et al.*, 2023).

2. Major insect pests of brinjal

2.1. Brinjal shoot and fruit borer,*Leucinodesorbonalis*Guenee (Pyraustidae: Lepidoptera)

Host range: It is mostly monophagous sometimes attack other wild plants belonging to Solanaceae family *S. tuberosum, S. aculeatissimum, S. Indicum, S. myriacanthum, S. torvum, Lycopersiconesculentum*,*Capsicum annum*, mango, sweet potato, and peas (Singla *et al.*, 2018). The brinjal shoot and fruit borer (BSFB), *Leucinodesorbonalis*, is the most destructive pest of brinjal, causing up to 70% yield losses in some regions. The larvae bore into the tender shoots and fruits of the plant, causing wilting of shoots and rendering the fruits unmarketable. Larval feeding results in holes and tunnels inside the fruits, making them unfit for consumption. This pest has multiple generations per year and is difficult to control due to its concealed feeding habits.However, at the severe infestation, the loss may exceed to an extent of more than 90% (Ghosh *et al.*, 2003). Raina and Yadav, (2017) 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. Newly formed adult usually found on the lower leaf surfaces Alam *et al.*, (2003) this pest completed 5 overlapping generations per year. Patel *et al.,* (1988) observed the highest shoot infestation during mid-September while peak fruit infestation during mid-November. Ghosh and Senapati (2009) also found the low infestation (18.66%) of borer in the third week of May, which got severe (75.50% infestation) in the first week of August, and moderate (42.64% infestation) in the last week of September.

2.2. Aphids, *Aphis gossypii*Glover and *Myzuspersicae*Sulzer, (Aphidiae: Hemiptera)

It is a highly polyphagous species infesting over 900 plant species around the world (Blackman and Eastop, 2000). In the tropics, it feeds on crops like cotton, cucurbits, eggplant, coffee, cocoa, peppers, and okra (Luo *et al.*, 2016). Aphids are small, sap-sucking insects that infest brinjal plants, particularly during the early stages of growth. They feed on the underside of leaves, leading to curling, yellowing, and reduced plant vigor. Aphids are also vectors of viral diseases, such as cucumber mosaic virus (CMV), which can further damage brinjal crops. Infestations are often more severe in warm, humid conditions, and can significantly reduce yields if left unmanaged. In case of severe infestations causes curling, deformed young leaves, and hindering photosynthesis activity. It produces honeydew, which leads to the development of sooty mold fungus. (Blackman and Eastop, 2006; Capinera, 2001).

2.3. Whiteflies, *Bemisiatabaci*Gennadius (Aleyrodidae: Hemiptera)

It is distributed worldwide inhabiting every continent of the world except Antarctica (Kanakala and Ghanim, 2019). Thisis highly polyphagous and known to feed on more than 500 host plant species belonging to 60 families including greenhouse and open field crops. It mainly attacks several solanaceous, field crops, and ornamental crops, including tomato, eggplant, chili, potato, cotton, okra, tobacco, and weeds (Kunjwal and Srivastava, 2018). Whiteflies, especially the species *Bemisiatabaci*, are another serious pest of brinjal. These insects feed by sucking sap from the leaves, causing wilting, leaf drop, and reduced photosynthetic efficiency. Whiteflies are notorious vectors of plant viruses, particularly the tomato yellow leaf curl virus (TYLCV), which can devastate brinjal crops. In addition to direct feeding damage, whiteflies excrete honeydew, which promotes the growth of sooty mold, further hindering plant growth.When the populations are high they secrete large quantities of honeydew, which favors the growth of sooty mold on leaf surfaces and reduces the photosynthetic efficiency of the plants (Khan and Wan, 2015).

2.4. Jassids/Leafhoppers, *Amrascabiguttulabiguttula* Ishida (Cicadellidae: Hemiptera)

Jassids, or leafhoppers, are small, mobile insects that feed on brinjal by piercing and sucking plant sap from the leaves. This feeding activity results in characteristic symptoms such as yellowing of leaf margins (hopper burn) (Srinivasan, 2009), stunted plant growth, and reduced yields. Severe infestations can cause significant damage, leading to defoliation and poor fruit development. Later it leads to leaf chlorosis, stunted growth, and low yield of plants (Ramzan, *et al.,* 2020).

2.5. Red Spider Mites,*Tetranychusurticae*Koch (Acari: Tetranychidae)

Red spider mites are common in dry and hot conditions and are particularly damaging to brinjal plants during drought periods. They feed on the undersides of leaves, causing them to develop pale, stippled spots and eventually turn bronze or brown. Severe infestations lead to leaf drop, reduced plant vigor, and poor fruit production. Mite infestations often go unnoticed until significant damage has occurred. Consequently, reduction in chlorophyll content in the leaves, leading to the formation of white or yellow speckles on the leaves, and the photosynthetic rate is reduced (Bensoussan *et al.,* 2016). Under high population densities, the mites move to use strands of silk to form a ball-like mass, which will be blown by winds to new leaves or plants, in a process known as ballooning. This pest causes more damage in the dry period of the year (Rao *et al.,* 2018; Mutthuraju, 2013).

2.6. Thrips, *Thripstabaci*Linderman and*Thripspalmi*Karny (Thripidae: Thysanoptera)

It is extremely polyphagous, recorded on more than 200 plant species from more than 36 plant families. It is a pest of Cucurbitaceae, solanaceous vegetables, and field crops, including brinjal, bean, cabbage, chili, cowpea, cucumber, lettuce, melon, okra, onion, pea, pepper, potato, pumpkin, squash, watermelon, capsicum, chrysanthemum, soybean, cotton, sunflower, tobacco, sesame and mung bean (Capinera, 2001). Thrips are tiny, slender insects that feed on the tender parts of brinjal plants, including leaves, flowers, and young fruits. Their feeding activity results in silvering or stippling on the leaf surface, distortion of new growth, and a reduction in fruit size and quality. Thrips are also vectors of plant viruses, which can exacerbate the damage caused by their feeding. Economical point of view, there is a very low threshold for fruit damage, for example, EIL for eggplant is 0.08 adults per leaf in Japan (Kawai, 1990). Rashid *et al.,* (2013) who reported the incidence of the thrips in the third week of December (0.65 thrips/5 cm twig) and a peak (22.67 thrips/5 cm twig) during the last week of February when the crop was 133 days old.

2.7 Epilachnabeetle/hadda beetle/spotted leaf beetle, *Henosepilachnavigintioctopunctata*Fabricius, *H. dodecastigma*Wiedemann (Coccinellidae: Coleoptera)

It is polyphagous, and feeds predominantly on cucurbits, brinjal, potato, Ashwagandha, and kidney bean. It also feeds on other solanaceous plants such as *S. nigrum*, *S. xanthocarpum*, *S. torvum*, *Datura* sp., *Physalis* sp., and *Withaniasomnifera* (L.) (David, 2001; Naz *et al.,* 2012).

Both grub and adults are having chewing mouthparts, they scrape the chlorophyll from the lower epidermal layers of the leaves, gives a stifled appearance. Thus feeding results in a typical ladder-like window. The windows will dry and drop off, leaving holes in the leaves. In severe infestations, several windows coalesce together and lead to skeletonization, the formation of a papery structure on the leaf (Deshmukh *et al.,* 2012).

2.8 Stem borer,*Euzopheraperticella*Rag. (Phycitidae: Lepidoptera)

After hatching, the larva starts boring into the main stem near ground level. Mostly they bore in the branching area or leaf axils, and seal the entry holes with excretory materials. Larvae feed downward along the length of the stem, results in wilting, stunted growth, and withering of the whole plant. The later stages of plant growth are most vulnerable to this insect and fruit-bearing capacity is severely affected (Javed *et al.,* 2017).

2.9 Brown leaf hopper, *Cestiusphycitis*Distant (Cicadellidae: Hemiptera)

Bangladesh, India, China, Myanmar, Africa, Pakistan, Srilanka, Taiwan, and the Philippines. Adults are small light brown color, measuring around 3 mm long. While males are a little smaller in body length, nymphs are creamy white, wingless, and turn brownish with the advancement of age. Nymphs and adults remain in veins of the lower leaf surface and suck the sap and inject a toxin. The leaves turn yellow, reduce in size, shortened petioles, crinkle, and curl backward. Excessive growth of branches plants become stunted, bushy, and conversion of floral parts into leafy structures. In severe cases, the plant may get killed and fruiting will be rare. It acts as a vector of little leaf disease (Satyagopal*et al.,* 2014).

2.10 Root-knot nematode RKN,*Meloidogyne incognita*(Kofold& White) Chitwood (Heteroderidae:Tylenchida)

These are obligate parasites of vascular tissues of plant roots. Root lesions, reduction in plant growth, and deformation are the additional symptoms of RKN. The infected plant shows a reduced root system with fewer feeder roots (Anwar and McKenry, 2010). Extensive galling and root damage is associated with nematode infection. Vegetable crops are among the most susceptible and worst affected by these nematodes (Sharma *et al.*, 2006).

3. Current management strategies for brinjal pests

3.1. Chemical control

Chemical insecticides are widely used in brinjal pest management, particularly for controlling the brinjal shoot and fruit borer, aphids, whiteflies, and other major pests. However, the indiscriminate use of chemicals has led to the development of pesticide resistance, resurgence of secondary pests, and negative environmental and health impacts.

- **Organophosphates** and **pyrethroids** are commonly used to control pests like aphids, whiteflies, and borers.
- **Neonicotinoids** are effective against sucking insects such as aphids and whiteflies.
- **Insect growth regulators (IGRs)** are sometimes used to disrupt the life cycles of pests such as jassids and mites.

While chemical control is often effective in the short term, it poses risks to beneficial insects like pollinators and natural enemies, and the excessive use of pesticides can lead to environmental contamination.

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 (Sahu *et al.*, 2023;Sharma and Sharma, 2010). According to (Raina and Yadav, 2018), 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 (Raina and Yadav, 2018; Srinivasan, 2008), found that Tracer-45 SC(Spinosad), Bactoil, Proclaim5 SG demonstrated significantly higher mortality against 4th instar larvae of BSFB while (Raina and Yadav, 2018; Srinivasan, 2008) reported from his experiment that Chlorantraniliprole is the best insecticides among treatments for effective management of Brinjal shoot and fruit borer followed by Spinosad. Sahu *et al.*, 2023 who recorded most effective against *L. orbonalis* with treatment Emamectin benzoate 5 SG @ 200 g /ha.Chemicals like imidacloprid 17.8 SL @ 0.5 ml/l, cyantraniliprole 10.26 OD @ 1 ml/l, oxydemeton methyl 25 EC @ 1.5 ml/l, acetamiprid 20 SP @ 0.5 g/l, thiamethoxam 25 WG @ 0.3 g/l, acephate 95 SG @ 0.3 g/l, clothianidin 50 WDG @ 0.25 g/l (Hemadri *et al.*, 2018) cypermethrin 25 EC @ 0.4 kg *a.i.*/ha (Bala*et al.*, 2016) and botanicals like Nimbecidine 1500 ppm @ 1.00 l/acre, Nimbecidine 300 ppm @ 1.00 l/acre, Neem oil 5% and NSKE 5% (Kumar *et al.*, 2020) was found effective for sucking insect pests.New insecticides like Emamectin benzoate + thiamethoxam 3.0% + 12.0%WG, spinosad 45%SC, emamectinbenzoate 5%SG, novaluron + indoxacarb 0.25% + 4.5%SC, flubendamide 20%WG and chlorantraniliprole 18.5%SC has proved to be effective treatment against hadda beetle (Birjhu*et al.*, 2020).Spray insecticides like Carbaryl 50 WP + wettablesulphur 50 WP @2 kg, Quinalphos 25 EC @1.5 L + Neem oil 1@.0 L, NSKE @ 5%, Azadirachtin 1.0% @1.0-1.5 L, Fenpropathrin 30 EC @250-340 ml, Thiodicarb 75 WP @ 625-1000 g from 30 DAT at 15 days interval against stem borer (Satyagopal*et al.*, 2014). Systemic insecticides of neonicotinoid, such as clothianidin, dinotefuran, imidacloprid, thiamethoxam, chlorantraniliprole, spinosad and flupyraifurone as foliar applications can control the whitefly population for sucking insects (Shinde *et al.*, 2018).New-molecule like rynaxypyr and cyazypyr, spinetoram, chlorofenapyr, formatenate hydrochloride, Clothianidin and tolfenpyrad, Spinosad, 2SC can be included in a management program for controlling Thrips (Seal, 2011).Spray botanical like NSKE (5%) otherwise insecticides like fenazaquine 10% EC @ 500 ml in 200 l of water/acre or fenpropathrin 30% EC @ 100-136 ml in 300-400 l of water/acre or dicofol 18.5% EC @ 540-1080 ml in 200-400 l of water/acre or malathion 50% EC @ 600 ml in 200-400 l of water/acre or flumite/flufenzinzine 20% SC @ 160-200 ml in 200-400 l of water/acre or propargite 57% EC @ 400 ml in 160 l of water/ acre or spiromesifen 22.9% SC @ 160 ml in 200 l of water/acre or phorate 10% CG @ 6000 g/acre spirodiclofen is effective against the two-spotted spider mite (Bostanian *et al.*, 2003).

3.2. Biological control

Biological control methods involve using natural enemies such as predators, parasitoids, and entomopathogens to manage pest populations. This approach has gained increasing attention due to its eco-friendly nature and long-term effectiveness.

- ***Trichogramma* spp.**, a genus of egg parasitoids, are released to target the eggs of *Leucinodesorbonalis* and prevent the development of larvae.
- **Coccinellids** (ladybird beetles) and lacewings are predators of aphids and whiteflies, helping to naturally regulate their populations.
- ***Bacillus thuringiensis*** (Bt), a microbial insecticide, has been successfully used against larvae of *Leucinodesorbonalis* and other lepidopteran pests.

Despite its advantages, biological control is often underutilized due to the lack of availability of biocontrol agents and limited farmer awareness.

According to (Raina and Yadav, 2018; Srinivasan, 2008) 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 Mandal *et al.*, (2010). Similarly, although the efficacy of NPV is lower, it can be used as a bio control agent (Raina and Yadav, 2018). 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].Entomopathogenic fungi like Bea*uveriabassiana*, *Metarhiziumanisopliae*, *Isariafumosoroseus*, *Verticilliumlecanii*, and *Ashersonia* spp., are the potential biocontrol agents for controlling *B. tabaci* (Abdel-Raheem and Lamya, 2016).Release of endo-parasite, *Aresconenocki*, *Chrysoperla* spp. also helps in managing the pest for jassids (Sahito*et al.*, 2018).Conserve predators such as *Eocantheconafurcellata*, *Rhinocorisfuscipes*, etc for haddabeetle (Satyagopal*et al.*, 2014).Conserve larval parasitoids such as *Pristomeruseuzopherae*, *P. testaceusetc* for brinjal stem borer (Halder *et al.*, 2017).Minute pirate bugs*Oriusinsidiosus* is a predator should be encouraged in the management of thrips (Seal, 2004).Conserve parasitioids like *Encarsia Formosa*, *Eretmocerus* spp., *ChrysocharisPentheus* for *B. tabaci*(Shah *et al.*, 2015).Conserve predators such as green lacewings (*Malladabasalis* and

Chrysoperlacarnea), predatory mites (*Amblyseiusalstoniae*, *A. womersleyi*, *A. fallacies*, *A. swirskii*, *Mesoseiuluslongipes*, *Neoseiuluscalifornicus*, *Galendromusoccidentalis* and *Phytoseiuluspersimilis*), coccinellid beetles (*Stethoruspunctillum*, stapylinid beetles (*Oligota* spp.), cedidomyiid fly (*Anthrocnodaxoccidentalis*), gall midge (*Feltiellaminuta*) etc for spidermite (Satyagopal*et al*., 2014).Bio nematicides and synthetic nematicides like Tervigo 2% SC @2.5 L, Micronema @30 L, Bio-Nematon @2 L, Rugby 10 G @24 kg, Vydate 24% SL @ 4 L, fenamiphos 40 EC, ethoprophos 20 EC), and fosthiazate 10% GR helps to manage RKNs on brinjal (CAB International, 2017).

3.3. Cultural control

Cultural practices play a crucial role in minimizing pest infestation and reducing the reliance on chemical control. Key cultural control measures include:

- **Crop rotation**: Rotating brinjal with non-host crops can help break the life cycle of pests such as borers and aphids.
- **Intercropping**: Planting brinjal alongside pest-repelling crops, such as garlic or marigold, can help reduce infestations of aphids, whiteflies and jassids.
- **Trap cropping**: Using trap crops like okra to attract and manage populations of *Leucinodesorbonalis* has shown success in reducing damage to brinjal.
- **Field sanitation**: Regular removal of infested plant debris and weeds can reduce overwintering sites for pests, lowering the likelihood of future infestations.

3.4. Integrated Pest Management (IPM)

IPM is a comprehensive pest management strategy that integrates multiple control methods, including chemical, biological, and cultural practices, to sustainably manage pests with minimal environmental impact. IPM in brinjal involves:

- **Monitoring and scouting**: Regular monitoring of pest populations helps in the early detection of infestations and reduces the need for heavy pesticide applications.
- **Threshold-based pesticide application**: Pesticides are applied only when pest populations exceed economic thresholds, minimizing overuse.
- **Promotion of resistant varieties**: Developing and planting brinjal varieties that are resistant to key pests, particularly *Leucinodesorbonalis*, can help reduce the need for chemical control.

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.

Similarly, the module with three different component as per Dutta*et al.*, (2011), *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 (Raina and Yadav, 2018; Srinivasan, 2008).

4. Challenges and future directions

4.1. Pesticide resistance

The overuse of chemical pesticides has led to resistance in pests like aphids, whiteflies, and the brinjal shoot and fruit borer. Future research should focus on developing new classes of pesticides with different modes of action and rotating their use to manage resistance.

4.2. Lack of awareness and resources

Many smallholder farmers lack access to information and resources to adopt IPM and other sustainable pest management practices. Strengthening agricultural extension services and providing training on IPM practices are crucial for improving adoption rates.

4.3. Climate change

Climate change is expected to affect the distribution and severity of pest infestations. Developing pest forecasting models and promoting climate-resilient crop varieties will be important in mitigating the impact of climate change on brinjal pest management.

6. Conclusion

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Brinjal cultivation faces significant challenges from a variety of insect pests, particularly the brinjal shoot and fruit borer, aphids, and whiteflies. While chemical control remains the dominant strategy for managing these pests, the long-term sustainability of brinjal production will require a shift toward integrated pest management (IPM). By incorporating biological control agents, cultural practices, and threshold-based pesticide applications, farmers can achieve effective pest management while minimizing environmental and health risks. Future research should focus on developing pest-resistant varieties and promoting the adoption of IPM to ensure sustainable brinjal production.

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Comment [i4]: The DOI for each reference in the references list must be mentioned if available .

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