Overview of Brinjal (*Solanum melongena* 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 on 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 cultural, biological and chemical control methods to promote sustainable brinjal production.

Keywords: Brinjal, (*Solanum melongena* L.), damage mechanism, current management practices, IPM and insect pests.

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(Sahu *et al.,* 2023). 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.Various methods have been employed to manage pest populations in brinjal, with chemical control being a prevalent strategy to maintain pest levels below the economic injury level (EIL). However, many of the insecticides used have not demonstrated satisfactory effectiveness in controlling these pests (Sahu *et al.,* 2023).

2. Major insect pests of brinjal

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

It is a largely monophagous pest that primarily targets brinjal. However, it can also infest other wild plants in the Solanaceae family, such as potato, kateli, sesame, *Solanum myriacanthum,* as well as common crops like tomato, chili, 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, loss will even exceed an extent more than 90%(Ghosh *et al.,* 2003). Adults often mate at night or in the early morning, according to Raina and Yadav (2017). The mating time varies as follows: 6–9 hours before mating and 4-6 days after mating. Newly developed adults are often found on the undersides of the leaves. This pest produced five overlapping generations annually, according to Alam *et al.* (2003). Patel *et al.* (1988) observed that fruit infestation by the brinjal shoot and fruit borer reached its peak around mid-November, while the highest level of shoot infestation was noted in mid-September. Further studies by Ghosh and Senapati (2009) found that infestation rates were comparatively low at 18.66% in the third week of May, escalated to a severe 75.50% during the first week of August, and then reduced to a moderate 42.64% by the last week of September.

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

This species is highly polyphagous, affecting more than 900 plant species worldwide (Blackman and Eastop, 2000). In tropical regions, it is known to infest a range of crops, including 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.The insect produces honeydew, which facilitates the development of sooty mold fungus. In cases of heavy infestation, it can cause leaf curling, deformities in young leaves, and reduce photosynthetic efficiency (Blackman and Eastop, 2006; Capinera, 2001; Uma *et al.,* 2024).

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

It is distributed globally, except in Antarctica (Kanakala and Ghanim, 2019). It is highly polyphagous, feeding on over 500 plant species from 60 families, affecting both greenhouse and field crops. It primarily targets various solanaceous and ornamental plants, including tomato, eggplant, chili, potato, cotton, okra, tobacco, and several types of weeds (Kunjwal and Srivastava, 2018).Whiteflies, especially the species *Bemisiatabaci*, is an 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 populations are high, they release a lot of honeydew, which encourages the formation of sooty mold on leaf surfaces and lowers the plants ability to photosynthesize (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.As the infestation progresses, it leads to reduced plant productivity, stunted growth, and leaf chlorosis (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 the 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.Leaves affected by this pest have reduced chlorophyll levels, causing white or yellow specks to appear on their surfaces (Bensoussan *et al.,* 2016). When populations are high, mites form a ball-like mass with silk strands, which can be carried by the wind to infest new plants. The pest is particularly problematic during the dry season, as noted by Rao *et al.* (2018) and Mutthuraju (2013).

2.6. Thrips, *Thrips tabaci* Linderman and*Thrips palmi* Karny (Thripidae: Thysanoptera)

This pest exhibits wide-ranging polyphagy, affecting over 200 plant species from more than 36 plant families. Among the solanaceous vegetables and field crops it infests are brinjal, beans, cabbage, chili, cowpea, cucumber, lettuce, melon, okra, onion, pea, pepper, potato, pumpkin, squash, watermelon, capsicum, chrysanthemum, soybean, cotton, sunflower, tobacco, sesame, and mung beans (Capinera, 2001). It is 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.The economic injury level (EIL) for fruit loss is quite low; in eggplant cultivation in Japan, for example, the EIL is 0.08 adults per leaf (Kawai, 1990). Thrips populations reached a peak density of 22.67 thrips per 5 cm twig in the final week of February, when the crop was 133 days old, with an earlier incidence peak in the third week of December at 0.65 thrips per 5 cm twig (Rashid *et al.*, 2013).

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

This polyphagous pest primarily feeds on crops such as kidney beans, potatoes, brinjal, ashwagandha, and various cucurbits. It also targets other solanaceous plants, including *Withaniasomnifera* (L.), *Datura* species, *Physalis* species, *Solanum nigrum*, *S. xanthocarpum*, *S. torvum*, among others (David, 2001; Naz *et al.*, 2012). The grubs and adults use their chewing mouthparts to remove chlorophyll from the lower epidermal leaf layers, creating a suffocated appearance. This feeding behavior produces distinctive "windows" on the leaves, which, as they dry and fall out, leave perforations. In severe cases, combined feeding results in skeletonized leaves or a thin, papery leaf structure (Deshmukh *et al.*, 2012).

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

After emerging, the larva begins to burrow into the main stem just below the soil surface. They typically enter through leaf axils or near the branching points and often seal the entrance with excretory substances. As the larvae feed down the stem, they cause wilting, stunted growth, and general scorching of the plant. This pest significantly impacts the fruiting potential and poses a serious threat to plants during their later growth stages (Javed *et al.*, 2017).

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

The adults of this pest are small, measuring about 3 mm in length, and are light brown in color, with males being slightly smaller than females. The nymphs start as creamy white and wingless before turning brown. Both adults and nymphs reside in the leaf veins, where they inject toxins and feed on the sap. This feeding behavior causes the leaves to curl, wrinkle, and shrink their petioles, often turning yellow. Excessive feeding can result in bushy, stunted growth, and the transformation of flower parts into leafy structures. In severe cases, the frequency of fruiting decreases, and the plant may die. This pest is also responsible for transmitting little leaf disease (Satyagopal*et al.*, 2014).

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

It is obligate parasites that target the vascular tissues of plant roots. Infected plants often exhibit symptoms such as deformation, root lesions, and stunted growth. Anwar and McKenry (2010) noted that plants affected by these nematodes typically have a diminished root system with fewer feeder roots. Nematode infections lead to significant galling and damage to the root structure. Sharma *et al.* (2006) found that vegetable crops are particularly susceptible and severely impacted by these pests.

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.Tests of chemical pesticides demonstrated that flubendiamide, spinosad, and chlorfenapyr effectively reduced infestation levels of *L. orbonalis* in eggplant, leading to increased production (Sahu *et al.,* 2023). Additionally, the application of Bt, Methoxyfenozide, and Emamectin Benzoate lessened the overall damage from the pest while promoting higher yields of brinjal (Sahu *et al.,* 2023; Sharma and Sharma, 2010). Raina and Yadav (2018) and Sahu *et al.* (2023) reported that treatment with Emamectin Benzoate resulted in the lowest average percentage of fruit infestation at 40.1%, indicating effective pest management.It was followed by Cypermethrin with 40.43% fruit infestation (Raina and Yadav, 2018; Srinivasan, 2008), found that Tracer-45 SC(Spinosad), Bactoil, Proclaim 5 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.The most effective treatment against *L. orbonalis* identified by Sahu *et al.* (2023) was Emamectin Benzoate 5 SG at a rate of 200 g/ha. Other recommended insecticides included Imidacloprid 17.8 SL at 0.5 ml/l, Cyantraniliprole 10.26 OD at 1 ml/l, Oxydemeton Methyl 25 EC at 1.5 ml/l, Acetamiprid 20 SP at 0.5 g/l, Thiamethoxam 25 WG at 0.3 g/l, Acephate 95 SG at 0.3 g/l, and Clothianidin 50 WDG at 0.25 g/l (Hemadri et al., 2018). Cypermethrin 25 EC at 0.4 kg *a.i.*/ha (Bala *et al.*, 2016) and botanical options such as Nimbecidine at 1500 ppm and 300 ppm (1.00 l/acre), Neem oil at 5%, and NSKE at 5% (Kumar et al., 2020) have also been effective in managing sucking insect pest issues.Birjhu*et al.* (2020) reported that insecticides like Emamectin Benzoate combined with Thiamethoxam, Spinosad, Novaluron with Indoxacarb, Flubendamide, and Chlorantraniliprole have shown high efficacy against the hadda beetle. For stem borer management, Satyagopal*et al.* (2014) suggested insecticide combinations including Carbaryl 50 WP with wettable sulfur, Quinalphos with Neem oil, NSKE, Azadirachtin, Fenpropathrin, and Thiodicarb, applied from 30 days after treatment at 15-day intervals.Neonicotinoid systemic insecticides such as Spinosad, Flupyradifurone, Imidacloprid, Thiamethoxam, Dinotefuran, Clothianidin, and Chlorantraniliprole effectively reduce whitefly populations when applied topically (Shinde *et al.*, 2018). For thrip management, newer molecules including Rynaxypyr, Cyazypyr, Spinetoram, Chlorfenapyr, and Tolfenpyrad can be utilized (Seal, 2011). Additionally, botanicals like NSKE at 5% or insecticides such as Malathion and Dicofol can be used at specified rates mixed with water for effective application.Effective control of two-spotted spider mites may be achieved using treatments like 50% EC, Flumite/Fluazine 20% SC, Propargite 57% EC, Spiromesifen 22.9% SC, or Phorate 10% CG, applied at recommended rates in water (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* sp.**, a genus of egg parasitoids, are released to target the eggs of *L.orbonalis* 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 *L.orbonalis* 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) and Srinivasan (2008), *Bacillus thuringiensis* resulted in the lowest average shoot infestation at 13.31%, while neem oil showed a slightly higher rate of 15.05%. Mandal et al. (2010) reported comparable results with *Beauveria bassiana* at 15.37% and *Metarhizium anisopliae* at 15.1%. Although its effectiveness is lower, NPV can still serve as a viable biocontrol option (Raina and Yadav, 2018). Additionally, various botanical oils have proven effective against the Brinjal shoot and fruit borer (BSFB). Neem oil at a 2% concentration was identified as the most effective treatment, reducing damage by 60.2% and 59.91% when Brinjal was cultivated in *Kharif* and Rabi seasons, respectively, which aligns with findings from other research. Nimbecidine at 2 ml per liter also resulted in a significant reduction of 57.42% in damage. Several biocontrol agents have been identified for managing *B. tabaci*, including entomopathogenic fungi such as *Beauveria bassiana*, *Metarhizium anisopliae*, *Isariafumosoroseus*, *Verticillium lecanii*, and *Ashersonia* species (Abdel-Raheem & Lamya, 2016). Sahito et al. (2018) highlighted the effectiveness of releasing endo-parasites like *Arescon enocki* and *Chrysoperla* species for managing jassid pests. Predators of the hadda beetle, such as *Rhinocorisfuscipes* and *Eocantheconafurcellata*, should also be preserved (Satyagopal*et al.*, 2014). For the brinjal stem borer, it is recommended to protect larval parasitoids like *Pristomeruseuzopherae* and *P. testaceus* (Halder *et al.*, 2017). Encouraging tiny pirate bugs like *Oriusinsidiosus* can help control thrips populations, while for *B. tabaci*, it is essential to conserve parasitoids such as *Encarsiaformosa*, species of *Eretmocerus*, and *Chrysocharispentheus* (Shah *et al.*, 2015). In terms of managing spider mites, predatory mites such as *Amblyseiusalstoniae*, *A. womersleyi*, *A. fallacies*, *A. swirskii*, *Mesoseiulus longipes*, *Neoseiulus californicus*, *Galendromus occidentalis*, and *Phytoseiulus persimilis*, along with coccinellid beetles like *Stethoruspunctillum*, and other predatory insects, should be preserved (Satyagopal*et al.*, 2014).

For root knot nematodes (RKNs), biopesticides such as Tervigo 2% SC at 2.5 L, Micronema at 30 L, Bio-Nematon at 2 L, Rugby 10 G at 24 kg, Vydate 24% SL at 4 L, Fenamiphos 40 EC, Ethoprophos 20 EC, and Fosthiazate 10% GR can be employed against RKNs in 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 *L.orbonalis* 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 *L.orbonalis*, can help reduce the need for chemical control.

The most effective models of IPM as per Dutta *et al.*, (2011)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.

Dutta *et al.* (2011) found that an integrated pest management approach combining a pheromone trap, mechanical control, and the use of Peak Neem, a neem-based insecticide, was highly effective in reducing damage to fruit and shoots while enhancing overall productivity. Additionally, Raina and Yadav (2018) and Srinivasan (2008) reported that the combination of Endosulfan with Deltamethrin (0.07% and 0.0025%, respectively) and Endosulfan with Fenvalerate (0.07% and 0.005%) yielded excellent results against the Brinjal shoot and fruit borer (BSFB), resulting in only 13.3% damage, significantly lower than the 69.8% damage observed in untreated control groups.

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.

5. Conclusions

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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