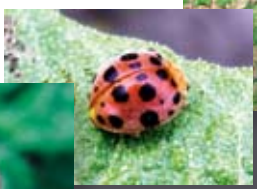
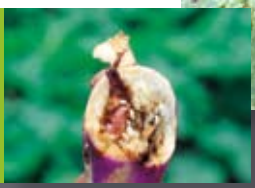
AVRDC
The World Vegetable Center

INSECT AND MITE PESTS ON EGGPLANT

A field guide for identification and management

R. SRINIVASAN





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AVRDC – The World Vegetable Center is an international nonprofit research institute committed to alleviating poverty and malnutrition in the developing world through the increased production and consumption of safe vegetables.

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FOREWORD

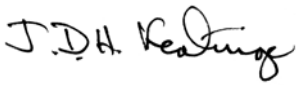
Eggplant is one of the most important vegetables in Asia, where more than 90% of the world's eggplant production occurs. Rich in nutrients, eggplant supplies vital vitamins, minerals, and dietary fiber to the human diet, especially in the rainy season, when other vegetables are in short supply for the rural and urban poor.

Attempts to control eggplant pests currently entail excessive use of pesticides. Intensive pesticide use in eggplant increases the cost of production, making this vegetable expensive for poor consumers. Pesticide misuse and residues pose serious risks to the health of growers, consumers, and the environment.

AVRDC – The World Vegetable Center developed and promoted an integrated pest management (IPM) strategy for the control of eggplant fruit and shoot borer in the Indo-Gangetic plains of South Asia in 2000–2005. Growers throughout the region are readily adopting this IPM strategy because it reduces pesticide use and labor requirements for eggplant cultivation, increases the economic return from eggplant, and leads to opportunities for expanding eggplant production. IPM measures already proven effective and economic in the Indo-Gangetic plains of South Asia can be easily adapted to other major eggplant-growing countries.

This field guide contains information on the major insect and mites damaging eggplant. The biology of each species is discussed. Detailed photographs showing damage symptoms allow for rapid identification of pest and disease problems. For each pest, IPM strategies for the topics are outlined.

Insect and mite pests on eggplant: a field guide for identification and management will be of practical assistance to eggplant growers and extension specialists worldwide to help them identify pest problems and initiate suitable control measures.



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INTRODUCTION

Eggplant (*Solanum melongena* L.), also called aubergine or brinjal, is one of the top ten vegetables in the world. It is grown on more than 2 million ha with a production of nearly 33 million t. China is the world's top eggplant grower, accounting for more than half of world acreage and India is second, with about one quarter of the world total; Indonesia, Egypt, Turkey, Iraq and the Philippines are the other major eggplant producing countries. Asia accounts for about 94 percent of the world eggplant area, with about 92 percent of world output (FAO 2007). India and Indochina are considered the centers of origin for eggplant (Vavilov 1951).

Eggplant is well adapted to high rainfall and high temperatures, and is among the few vegetables capable of high yields in hot-wet environments (Hanson et al. 2006). Eggplant contains nutrients such as dietary fiber, folate, ascorbic acid, vitamin K, niacin, vitamin B6, pantothenic acid, potassium, iron, magnesium, manganese, phosphorus, and copper (USDA 2009); the nutrients that it contributes to the diets of the poor are especially important during times when other vegetables are in short supply.

In the tropics, eggplant production is severely constrained by several insect and mite pests. The major pests include eggplant fruit and shoot borer, leafhopper, whitefly, thrips, aphid, spotted beetles, leaf roller, stem borer, blister beetle, red spider mite, and little leaf disease. Growers rely heavily on chemical pesticides to protect their eggplant crop. For instance, farmers in certain areas of Philippines spray chemical insecticides up to 56 times during a cropping season; the total quantity of

pesticide used per hectare of eggplant was about 41 liters of different brands belonging to the four major pesticide groups (Gapud and Canapi 1994; Orden et al. 1994). In Bangladesh, some farmers spray about 180 times during a cropping season (SUSVEG-Asia 2007). Pesticide misuse has adverse effects on the environment and human health and also increases the cost of production. The share of the cost of pesticide to total material input cost was 55% for eggplant compared with cabbage (49%) and tomato (31%) in the Philippines (Orden et al. 1994), and accounted for 40–50 percent in Bangladesh (SUSVEG-Asia 2007). Many farmers refrain from growing eggplant due to the cost of pesticides (Gapud and Canapi 1994).

This guide provides comprehensive information for eggplant growers and extension staff about the major insect and mite pests on eggplant and their management. The simple, low-cost integrated pest management (IPM) techniques outlined in this guide provide satisfactory, sustainable management and can help eggplant growers decrease their reliance on chemical pesticides. AVRDC – The World Vegetable Center developed, successfully validated, and promoted an IPM strategy for the management of eggplant fruit and shoot borer in South Asia from 2000-2005 (Alam et al. 2003; Alam et al. 2006).

Insect and mite pests on eggplant

Eggplant fruit and shoot borer (EFSB)
Leucinodes orbonalis Guenee
(Lepidoptera: Pyralidae)

Eggplant fruit and shoot borer is one of the most destructive pests on eggplant in South and Southeast Asia. It is found throughout the tropics in Asia and Africa, where it can reduce yield by as much as 70%. Hence, the farmers in the region rely exclusively on the application of chemical insecticides to combat EFSB, which has resulted in a tremendous misuse of pesticides in an attempt to produce damage-free marketable fruits. Despite intensive insecticide applications, the pest cannot be controlled due to its resistance to commonly used pesticides.

Biology

Egg: The adult females lay eggs singly or in groups of two to five on the under surfaces of leaves (Plate 1), tender shoots, flower buds, or the base of developing fruits. Each female lays about 250 eggs, which are creamy white soon after laying, but turn red before hatching. The egg period is three to five days.

Larva: The larva is creamy white to pink in color in the early stages. The grown-up larva is pink with sparse hairs on the warts on the body and a dark brown or blackish head (Plate 2). The full-grown larva measures about 16-23 mm in length. The larva usually has five instars, sometimes six. The larval period is about two weeks in summer and three weeks in winter.

Pupa: The larva pupates on the plant parts or plant debris on the soil surface, or rarely, under the soil. The pupation occurs in tough silken cocoons (Plate 3), and the pupa is dark brown in color. The pupa measures about 13 mm.

Plate 1: *Leucinodes orbonalis* - eggs

Plate 2: *Leucinodes orbonalis* - larva

The pupal period varies from one to two weeks.

Adult: The moth is white or dirty white with pale brown or black spots on the dorsum of thorax and abdomen (Plate 4). Wings are white with a pink or blue tinge, and have pink or brown and red spots on the forewings. The female is bigger than male, with a bulged abdomen. The female moth tends to curl its abdomen upwards. The adult life span is about a week; the females live longer than males.

Damage symptoms

EFSB is mostly monophagous, sometimes also feeds on tomato, potato, *Solanum indicum* L., *S. xanthocarpum* Schrad. & Wendl., *S. torvum* Swartz., and *S. nigrum* L. (David 2001; Alam et al. 2003). Upon hatching, the larva starts boring near the growing point or into the flower buds or fruits. During the early vegetative phase of the crop growth, it feeds on the tender shoots. Soon after boring into the shoots and fruits, the larva seals the entry hole with excreta. The larva tunnels inside the shoot and feeds on the inner contents. It also fills the feeding tunnels with excreta. This results in wilting of young shoots (Plate 5), followed by drying (Plate 6) and drop-off, which slows plant growth. In addition, it produces new shoots, delaying crop maturity.

During the early reproductive phase, the larva occasionally may feed on flower buds and flowers. However, it prefers to feed on the fruit rather than other plant parts during the fruiting stage of the crop. Damaged fruit exhibits boreholes on the surface (Plate 7), which often are sealed with excreta. The larva feeding inside the fruit creates tunnels filled with frass and fecal pellets (Plate 8). Hence, the fruit becomes unfit for marketing and consumption.

Plate 3: *Leucinodes orbonalis* - pupa

Plate 4: *Leucinodes orbonalis* - adult moth

Under heavy infestation, more than one larva will feed inside the same fruit.

Management

Any single method of pest management alone will not achieve a level of EFSB control acceptable to producers. A simple and economic IPM technique can provide satisfactory control.

- Avoid monoculture and follow crop rotation. As EFSB is practically a monophagous insect on eggplant, discontinuation of eggplant cultivation in a community for a few seasons will significantly reduce EFSB populations.

- Avoid growing eggplant seedlings near fields with standing crops, in or near fields where the crop was grown previously, or near dried eggplant heaps. If seedlings must be grown in those areas, cover the beds with 30-mesh nylon net to prevent the entry of EFSB moths.

- Choose resistant or moderately resistant cultivars available in the region. For instance, accessions or varieties such as EG058, Pusa Purple Long, Pusa Purple Cluster, Pusa Purple Round, H-128, H-129, Aushey, Thorn Pendy, Black Pendy, H-165, H-407, Dorley, PPC-17-4, PVR-195, Shyamla Dhepa, Banaras Long Purple, Arka Kesav, Arka Kusmakar, Punjab Barsati, Punjab Chamkila, Kalyanpur-2 and Gote-2 have been reported to be tolerant or resistant (Parker et al. 1995; Alam et al. 2003; Shivalingaswamy and Satpathy 2007). Except EG058, which is an AVRDC accession, most of the

Plate 5: Wilted shoot of eggplant damaged by *Leucinodes orbonalis*

Plate 6: Dried shoot of eggplant damaged by *Leucinodes orbonalis*

other varieties are of Indian origin. Consult the local extension agency for availability of resistant or tolerant varieties.

- Promptly remove and destroy infested shoots and fruit at regular intervals until final harvest.

- Protect parasitoids such as *Trathala flavoorbitalis* (Cameron), *Eriborus sinicus* Holmgren, and *Pristomerus testaceus* Morley. Reduced use of synthetic pesticides will enhance the activities of these natural enemies. In addition, weekly releases of egg parasitoid, *Trichogramma chilonis* Ishii @ 1g parasitized eggs/ha/week and larval parasitoid, *Bracon habetor* Say @ 800-1000 adults/ha/week could be followed (Alam et al. 2006a)

- Install EFSB sex pheromone lures in traps at the rate of 100 traps per hectare. Place the traps either at canopy level or at slightly above the canopy level for effective attraction.

Plate 7: *Leucinodes orbonalis* feeding damage on eggplant fruit

Plate 8: *Leucinodes orbonalis* feeding tunnels filled with excreta inside the damaged eggplant fruit

Leafhopper
Amrasca devastans Distant
(Hemiptera: Cicadellidae)

The preferred scientific name for this leafhopper is *Amrasca biguttula biguttula* Ishida (CABI 2007). It occurs in several countries including India, Bangladesh, China, Myanmar, North Africa, Pakistan, Philippines, Sri Lanka, and Taiwan. Relatively dry (mean temperature around 32°C) and humid (RH around 70%) weather favors population build-up.

Biology
Egg: Adult females lay eggs along the midrib and lateral veins of the leaves. The egg period is 4 to 11 days.

Nymph: The nymphs resemble the adults, but lack wings (Plate 9). Instead, they have slightly extended wing pads. They are pale green in color. They tend to move sideways when disturbed. The nymphal period varies from one to four weeks depending on the temperature.

Adult: The adults are wedge-shaped, pale green insects (Plate 10). They have fully developed wings with a prominent black spot on each forewing. The adults may live for one to two months.

Damage symptoms
Both nymphs and adults suck the sap from the lower leaf surfaces through their piercing and sucking mouthparts. While sucking the plant sap, they also inject toxic saliva into the plant tissues, which leads to yellowing. When several insects suck the sap from the same leaf, yellow spots appear on the leaves, followed by crinkling, curling, bronzing, and drying, or "hopper burn" (Plate 11). Leafhoppers also damage in okra, cotton, and potato.

Plate 9: *Amrasca devastans* - nymphs

Plate 10: *Amrasca devastans* - adult

Management

- Choose tolerant or resistant cultivars with hairy leaves, as the length and density of the trichomes (hairs) repel leafhoppers. Indian cultivars such as Manjari Gota, Vaishali, Mukta Kesi, Round Green, and Kalyanipur T3 and Bangladeshi variety Bagun 6 are reported to be less susceptible or tolerant to damage (Parker et al. 1995; Rashid et al. 2003). Consult the local extension agency for the availability of resistant or tolerant varieties.

- Monitor the insects with yellow (570-580 nm) sticky traps placed at random in the field.

- Grow okra as a trap crop along the borders of an eggplant field; if pesticides are required to control an infestation, they can be applied to the trap crop.

- Avoid the use of broad-spectrum pesticides to encourage the performance of natural enemies. Generalist predators such as ladybird beetles and green lacewings are highly efficient in preying on leafhopper nymphs and adults. Parasitoids such as *Anagrus flaveolus* Waterhouse and *Stethynium triclavatum* Enock are effective against leafhopper (Subba Rao 1968; Parker et al. 1995).

- Use neem-based biopesticides at recommended doses. If commercial neem formulations are not available, neem seed kernel extract (NSKE) @ 5% can be sprayed.

- Use only those systemic pesticides recommended by the local extension service. Do not use the same compound or pesticide group continuously to avoid the development of pesticide resistance in insects.

Plate 11: Hopper burn caused by *Amrasca devastans*

Whitefly
Bemisia tabaci Gennadius
(Hemiptera: Aleyrodidae)

The whitefly is widely distributed in tropical and subtropical regions, and in greenhouses in temperate regions. *B. tabaci* is highly polyphagous and is known to feed on several vegetables including tomato, eggplant and okra, and on field crops and weeds. Hot and dry conditions favor the whitefly, while heavy rain showers drastically reduce its population build-up. This insect is active during the day and settles on lower leaf surfaces at night.

Biology
Egg: The females mostly lay eggs near the veins on the underside of leaves. They prefer hairy leaf surfaces to lay more eggs. Each female can lay about 300 eggs in its lifetime. Eggs are small (about 0.25 mm), pear-shaped, and vertically attached to the leaf surface through a pedicel. Newly laid eggs are white and later turn brown (Plate 12). The eggs are not visible to the naked eye, and must be observed under a magnifying lens or microscope. Egg period is about three to five days during summer and 5 to 33 days in winter (David 2001).

Nymph: Upon hatching, the first instar larva (nymph) moves on the leaf surface to locate a suitable feeding site. Hence, it is commonly known as a "crawler." It then inserts its piercing and sucking mouthpart and begins sucking the plant sap from the phloem. The first instar nymph has antennae, eyes, and three pairs of well-developed legs. The nymphs are flattened, oval-shaped, and greenish-yellow in color. The legs and antennae are

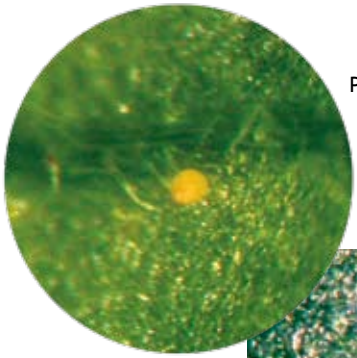

Plate 12: *Bemisia tabaci* - eggs

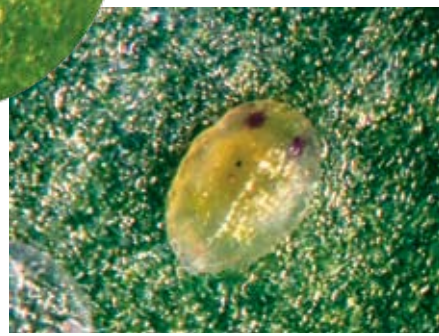

Plate 13: Red-eyed nymph of *Bemisia tabaci*

Plate 14: *Bemisia tabaci* - adults

atrophied during the next three instars and they are immobile during the remaining nymphal stages. The last nymphal stage has red eyes (Plate 13). This stage is sometimes referred to puparium, although insects of this order (Hemiptera) do not have a perfect pupal stage (incomplete metamorphosis). Nymphal period is about 9 to 14 days during summer and 17 to 73 days in winter (David 2001). Adults emerge from puparia through a T-shaped slit, leaving behind empty pupal cases or exuviae.

Adult: The whitefly adult is a soft-bodied, moth-like fly (Plate 14). The wings are covered with powdery wax and the body is light yellow in color. The wings are held over the body like a tent. The adult males are slightly smaller in size than the females. Adults live from one to three weeks.

Damage symptoms

Both the adults and nymphs suck the plant sap and reduce the vigor of the plant. In severe infestations, the leaves turn yellow and drop off. When the populations are high (Plate 15) they secrete large quantities of honeydew, which favors the growth of sooty mould (Plate 16) on leaf surfaces and reduces the photosynthetic efficiency of the plants.

Management

- Whitefly is a polyphagous insect; it has several host plants for feeding and survival ranging from cultivated crops to weeds. The field selected for eggplant or seedling production should be clean and not be located near any host plants and weeds.

Plate 15: Crowding of *Bemisia tabaci*

- Grow eggplant seedlings in insect-proof (50–64 mesh) net houses, net tunnels, greenhouses, or plastic houses.

- If the seedlings are produced under open field conditions, use yellow sticky traps at the rate of 1-2 traps/50-100 m^2 to trap the whiteflies. Hang the traps slightly above or at the canopy level for better trapping.

- Maintain a high standard of weed control in seedling production areas and crop fields to reduce the availability of alternate host plants.

- Plant fast-growing crops like maize, sorghum, or pearl millet in the border of the field to act as barriers to reduce whitefly infestations. Reflective plastic or straw mulches may reduce landing of whiteflies on eggplant crops.

- Neem formulations and imidacloprid (if available) could be applied as a soil drench or foliar application to control whitefly in eggplant seedlings.

- Use only those systemic pesticides that have been recommended by the local extension service. Do not use the same compound or pesticide group continuously to avoid the development of pesticide resistance in insects.

Plate 16: Sooty mould on *Bemisia tabaci* infested leaves

Thrips
Thrips palmi Karny
(Thysanoptera: Thripidae)

Thrips palmi is widely distributed in South Asia, Southeast Asia, and Oceania. Although it prefers to feed on cucurbits, occasionally it infests eggplant severely. Thrips attack eggplant mostly during the dry season.

Biology
Egg: The females lay eggs within the leaf tissues. Each female lays about 200 eggs. The egg is bean-shaped and yellowish-white in color; but may not be visible to the naked eye. The egg period varies from three days to two weeks depending on the temperature.

Larva: The larva resembles the adults but is smaller and lacks wing buds or wings. The larva has two active feeding stages, and the larval period varies from four days to two weeks depending on the temperature. Towards the end of the second larval stage, the larva stops feeding and moves down to the soil surface for pupation either in the soil or under plant debris.

Pupa: The pupal stage consists of pre-pupa and pupa (an inactive stage with no feeding). The pre-pupa has two shorter wing buds and flexible antennae. The pupa has longer wing buds and fused antennae with the body. The pre-pupal stage lasts for one to two days, and the pupal stage lasts for another one to three days.

Adult: The adult is yellow in color (Plate 17). It is very difficult to confirm the exact identity of thrips with the naked eye; they must be identified under microscopes

Plate 17: Adult of *Thrips palmi*

in laboratory conditions. Species in the genus *Thrips* have seven antennal segments. *T. palmi* and *T. tabaci* Lindeman are the two species found on most vegetables. *T. palmi* has red ocellar pigment, three ocelli on the top of the head in a triangular form, a pair of setae near the triangle, and abdominal pleurotergites without setae. *T. tabaci* has grey ocellar pigment, a pair of setae within the triangular form of ocelli, and abdominal pleurotergites with rows of microtrichia (Mound 1996). Adults live from two weeks to two months.

Damage symptoms

T. palmi is polyphagous and is known to feed on tomato, potato, hot pepper, watermelon, muskmelon, bottle gourd, cucumber, pumpkin, squash, etc. This species is commonly known as "melon thrips" because of its preferential feeding on cucurbits. The adults and larvae suck the plant sap. Thrips prefer to feed mostly on foliage, sometimes on fruit. Slightly infested leaves exhibit silvery feeding scars on the lower leaf surfaces, especially along the mid-rib and veins. In severe infestations, the leaves turn yellow or brown (Plate 18) and dry on the lower leaf surfaces. Infested fruit is scarred (Plate 19) and deformed.

Management

- Although *T. palmi* is a polyphagous insect, it overwhelmingly prefers to feed on cucurbits. The field selected for eggplant or seedling production should be located away from cucurbits.

- Grow eggplant seedlings in insect-proof (50–64 mesh) net houses, net tunnels, greenhouses, or plastic houses to avoid early infestation, especially

Plate 18: *Thrips palmi* feeding damage on the leaves

in the dry season.

- Predators such as green lacewings, predatory mites, and predatory thrips may feed on *T. palmi*. However, they are unable to provide complete control. Use blue sticky traps to monitor thrips at regular intervals and determine when other pest management controls are required.

- Use mulch and reflective materials in the field to reduce the incidence of *T. palmi*.

- Do not control the thrips infestation with broad-spectrum chemical pesticides, as a resurgence of *T. palmi* will likely occur. If necessary, spray a systemic pesticide after consulting with the local extension staff.

Plate 19: *Thrips palmi* feeding damage on the fruits

Aphid
Aphis gossypii Glover
(Hemiptera: Aphididae)

This is a cosmopolitan pest and highly polyphagous. It prefers to feed on cotton, cucurbits, eggplant, and okra. Aphids occur during the cool dry season.

Biology
Adult: Unlike many insects, most aphids do not lay eggs. They usually reproduce through parthenogenesis (development of embryo without mating with males) and are viviparous (give birth to nymphs directly rather than eggs). The adult color is highly variable and it varies from light green to greenish brown. Both wingless and winged forms occur. Winged forms are produced predominantly under high population density conditions, inferior host plant quality, etc. The wingless forms (Plate 20) are more common. They possess a pair of black-colored cornicles on the dorsal side of the abdomen. Aphids mostly are found in groups. Each female produces about 20 nymphs a day, which become adults in a week.

Damage symptoms
Although *A. gossypii* is polyphagous, it prefers to feed on cotton and cucurbit vegetables; it is commonly known as “cotton aphid” or “melon aphid.” Both the nymphs and adults possess piercing and sucking mouthparts. They occur in large numbers on the tender shoots and lower leaf surfaces, and suck the plant sap. Slightly infested leaves exhibit yellowing. Severe aphid infestations cause young leaves to curl and become deformed (Plate 21). Like whitefly, aphids also produce honeydew, which leads to the development of sooty mould.

Plate 20: Aphids on underside of leaf.

Management

- Although *A. gossypii* is a polyphagous insect, it overwhelmingly prefers to feed on cucurbits and cotton. Hence, the field selected for eggplant or seedling production should be located away from cucurbits and cotton.

- Grow eggplant seedlings in insect-proof (50–64 mesh) net houses, net tunnels, greenhouses, or plastic houses to avoid early infestation.

- The ladybird beetles (*Menochilus* sp. and *Coccinella* sp.) and green lacewings are efficient predators of aphids. Protect the population of these predators by avoiding the use of broad-spectrum pesticides. Inundative release of ladybird beetles @ 200 pairs per ha at fortnightly intervals can suppress the aphid population.

- *A. gossypii* can develop resistance to pesticides. Use only those pesticides that have been recommended by the local extension staff. Do not use the same compound or pesticide group continuously to avoid the development of pesticide resistance in insects.

Plate 21: *Aphis gossypii* - damage on the plant and honeydew deposit on the mulch surface

Spotted beetles
*Epilachna dodecastigma (*Wiedemann*)* and *E. vigintioctopunctata* Fabricius
(Coleoptera: Coccinellidae)

Spotted beetles are distributed from East Asia to South Asia and Australia. They are polyphagous, and feed predominantly on cucurbits, tomato, potato, and kidney bean as well as eggplant. These beetles are considered to be one of the most serious groups of pests damaging eggplant. In addition, they also feed on other solanaceous plants such as *S. nigrum*, *S. xanthocarpum*, *S. torvum*, *Datura* sp., *Physalis* sp. and *Withania somnifera* (L.) Dunal (David 2001).

Biology

Egg: The females lay eggs mostly on the lower leaf surfaces. Each female lays about 100-400 eggs. The egg is spindle-shaped and yellowish in color (Plate 22). Eggs are laid in clusters of 10-40. The egg period varies from two to five days.

Grub: The grub is creamy white or yellowish in color with black spiny hairs on the body (Plate 23). The grub period is two to five weeks depending on the temperature. Grubs pupate on the leaves and stem.

Pupa: The pupa resembles the grub but is mostly darker in color, although it sometimes is yellowish in color. The pupa bears spiny hairs on the posterior, but not the anterior, part of the body. The pupal period is one to two weeks.

Plate 22: Epilachna beetle - eggs

Plate 23: Epilachna beetle - grub

Adult: The subfamily Epilachninae contains plant-feeding ladybird beetles because most other ladybird beetles are predators, not plant pests. These brownish or orange-colored, hemispherical beetles (Plate 24) are larger than other ladybird species. *E. vigintioctopunctata* (in Latin, *viginti* means 20 and *octo* means 8) has 28 black spots on the forewing (elytra). *E. dodecastigma* (*dodeca* means 12 in Greek) has 12 black spots on the elytra. However, beetles with 14, 16, 18, 20, 22, 24 or 26 spots have been observed under field conditions, due to mating between females of *E. dodecastigma* and males of *E. vigintioctopunctata* (Lall and Mandal 1958).

Damage symptoms

The grub and adult have chewing mouthparts. Hence, they scrape the chlorophyll from the epidermal layers of the leaves. The feeding results in a typical ladder-like window (Plate 25). 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.

Management

- Choose resistant or moderately resistant cultivars available in the region. Varieties from India such as Arka Shirish, Hissar Selection 14, and Shankar Vijay have been reported to be tolerant or resistant to Epilachna beetle, especially *E. vigintioctopunctata* (Parker et al. 1995). Consult the local extension agency for the availability of resistant or moderately resistant varieties.

- All life stages are exposed on leaf surfaces, and the grub, pupae and adults can easily be found on

Plate 24: Epilachna beetle - adult

skeletonized leaves. Pick off the insects by hand and destroy, if the eggplant is grown in smaller plots.

- Protect the population of parasitoids such as *Pediobius foveolatus* (Crawford). Reduced use of synthetic pesticides may enhance the activities of natural enemies.

- If necessary, spray a selective pesticide after consulting with the local extension staff.

Plate 25: Ladder-like windows caused by *Epilachna* beetle feeding

Leaf roller
Eublemma olivacea Walker
(Lepidoptera: Noctuidae)

Leaf roller is an oligophagous insect that feeds mainly on eggplant, and sometimes on other solanaceous plants. Although it is not a serious pest, occasionally infestations can be severe.

Biology
Egg: The females lay eggs mostly on the younger leaves in groups and each group consists of 10-20 eggs. The egg period is 3-5 days.

Larva: The larva is stout and purple brown in color with long hairs on yellow or cream colored tubercles in the dorsal and lateral sides of the body (Plate 26). The larval period is two to three weeks.

Pupa: The full-grown caterpillars pupate within the folded leaves. The pupal period is about 7-10 days.

Adult: The medium-sized moth is olive green in color. The forewing is green, with a large triangular spot on the outer area toward the apex (Plate 27).

Damage symptoms
The larva folds the leaves longitudinally and feeds within the leaf folds (Plate 28) by scraping the green tissue. The damaged leaves turn brown, wither, and dry.

Plate 26: Leaf roller – larva

Plate 27: Leaf roller - adult

Management

- Monitor the crop for symptoms of damage. Remove and destroy the rolled leaves and caterpillars by hand when the infestation is light.

- If absolutely necessary, spray a pesticide in consultation with the local extension staff.

Plate 28: Feeding damage by Leaf roller

Stem borer
Euzophera perticella Ragonot
(Lepidoptera: Pyralidae)

This insect is limited in distribution. It is found mostly on the Indian subcontinent. This oligophagous insect feeds mainly on eggplant, and sometimes on other solanaceous plants such as tomato, potato, and chilies. Although it is not a serious pest, infestations occasionally can be severe. Monitor the crop for symptoms of damage.

Biology
Egg: The cream-colored eggs are laid either singly or in groups on the tender leaves, shoots, and petioles. The eggs are elongate and flat. The egg period varies from three to ten days.

Larva: The larva is white or yellowish white in color with several bristly hairs and an orange-brown or red head. The full-grown larva is 1.5 to 2 cm long. The larval period is about four to eight weeks depending on the temperature.

Pupa: Larvae pupate within silken cocoons inside the feeding tunnel in the stem or in the soil. The pupal period is about one to two weeks.

Adult: The medium-sized moth is pale in color. The forewing is pale yellow or grayish-brown in color, with black lines in the middle. The hind wings are white.

Damage symptoms
Soon after hatching, the larva starts boring into the stem near ground level. Mostly they bore in the branching area

or in leaf axils, and seal the entry holes with excretory materials. Larvae feed downward along the length of the main stem, which results in stunted growth or wilting and withering of the whole plant. The later stages of plant growth are most vulnerable to this insect.

Management

- Remove and promptly destroy the infested plants.

- Avoid ratoon cropping.

- Protect the population of parasitoids such as *Pristomerus euzopherae* Viereck. Reduced use of synthetic pesticides may enhance the activities of these natural enemies.

- Apply neem cake in the soil to reduce the incidence of stem borer.

- Apply a pesticide in the soil in consultation with the local extension staff, if absolutely necessary.

Blister beetle
Mylabris pustulata Thunberg
(Coleoptera: Meloidae)

These beetles are brightly colored insects that secrete a compound containing cantharidin when disturbed. Cantharidin, a terpenoid, produces blisters on human skin upon contact and hence these beetles are called "blister" beetles. This beetle is highly polyphagous and it feeds on the flowers of several plants in the families Convolvulaceae, Cucurbitaceae, Leguminosae, Malvaceae, etc. In general, this is a minor pest, although occasional outbreaks can occur.

Biology
The adult *Mylabris pustulata* is about 2.0-2.5 cm in length and bears red or reddish orange and black alternating bands on the forewing (elytra) (Plate 29). Each female lays about 100-2000 eggs depending on the quality of the food they ingest. The eggs are usually laid in the soil. Upon hatching, the grub feeds on soil-dwelling insects, including pests, and do not cause any damage to the crop. The grubs have several instars, with two or more different forms of larva. The mobile first instar grub is known as *triungulin* because it has three-clawed legs. During later instars, it becomes less active, and then pupates.

Damage symptoms
The adult is the destructive stage. As the insects feed on the plants' reproductive parts, they can cause significant yield losses.

Plate 29: *Mylabris pustulata* - adult

Management

- Pick off beetles by hand (wear gloves or use insect nets) and destroy.

- Chemical pesticides may not be effective as blister beetles are highly mobile insects. Synthetic pyrethroids may be used for a quick knock-down effect, but only when the blister beetle occurs in extremely high densities. Otherwise, synthetic pyrethroids will disrupt the efficiency of other eggplant IPM techniques.

Red spider mite
Tetranychus urticae Koch
(Acarina: Tetranychidae)

Red spider mite emerged as a serious pest of vegetable crops including eggplant, tomato, French bean and cucumber, and other field crops in South Asia, Southeast Asia, Africa, Europe, and Mediterranean countries. Low relative humidity favors the multiplication of mites and precipitation is the only important abiotic factor that restricts spider-mite populations.

Biology
T. urticae is commonly known as red spider mite or two-spotted spider mite. They are minute in size, and vary in color (green, greenish yellow, brown, or orange red) with two dark spots on the body. Eggs are round, white, or cream-colored; egg period is two to four days. Upon hatching, it will pass through a larval stage and two nymphal stages (protonymph and deutonymph) before becoming adult. The lifecycle is completed in one to two weeks. There are several overlapping generations in a year. The adult lives up to three or four weeks.

Damage symptoms
Spider mites usually extract the cell contents from the leaves using their long, needle- like mouthparts. This results in reduced chlorophyll content in the leaves, leading to the formation of white or yellow speckles on the leaves (Plate 30). In severe infestations, leaves will completely desiccate and drop off. The mites also produce webbing on the leaf surfaces in severe conditions (Plate 31). Under high population densities, the mites move to the tip of the leaf or top of the plant and congregate

Plate 30: White and yellow speckles caused by spider mites

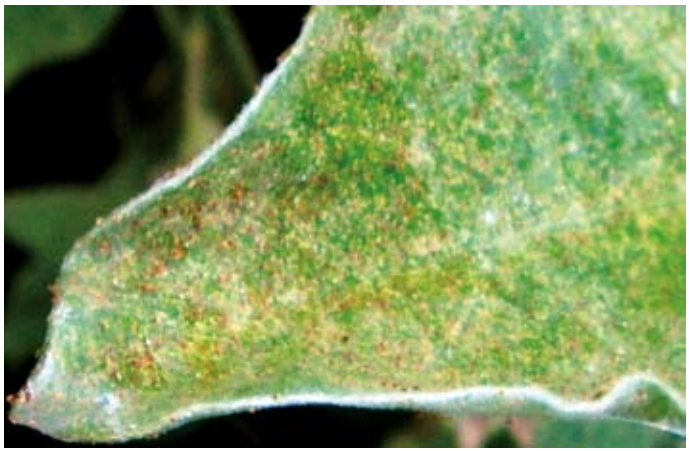

Plate 31: Webbing of leaves by spider mites

using strands of silk to form a ball-like mass (Plate 32), which will be blown by winds to new leaves or plants, in a process known as "ballooning."

Management

- Several predators of spider mites occur in most countries. For instance, *Stethorus* spp., *Oligota* spp., *Anthrocnodax occidentalis* Felt, *Feltiella minuta* Felt, etc. are known to occur in Taiwan (Ho 2000). As application of broad-spectrum pesticides may kill predators and lead to outbreaks of spider mites, avoid spraying broad-spectrum pesticides.

- Predatory mites such as *Phytoseiulus persimilis* Athias-Henriot and several species of *Amblyseius*, especially *A. womersleyi* Schicha and *A. fallacies* Garman can be used to control spider mites. They are more effective under protective structures and in high humidity conditions.

- Green lacewings (*Mallada basalis* Walker and *Chrysoperla carnea* Stephens) also are effective generalist predators of spider mites. A third instar grub of *C. carnea* could consume 25–30 spider mite adults per day; however, it needs supplemental food for long-term survival (Hazarika et al. 2001).

- Spray acaricides following local recommendations. Usually, the macrocyclic lactones (*e.g.* avermectins and milbemycins) are effective. However, continuous use may promote resistance in mites. Use proper pesticide rotations and follow window periods recommended by local extension staff.

Plate 32: Congregation of spider mites in the leaf tip

Little leaf disease transmitted by plant hopper

The disease occurs mostly late in the season. Little leaf disease in eggplant is caused by phytoplasma (mycoplasma-like organisms or MLOs). The disease is transmitted by grafting as well as by the plant hopper, *Hishimonus phycitis* Distant (Hemiptera: Cicadellidae), which also transmits the sesame phytoplasma disease. This disease has been reported in India. However, an eggplant phyllody disease caused by MLOs has been reported in Penghu Island in Taiwan (Yang and Chen 1988).

Damage symptoms

The infected plants have small clusters of leaves (Plate 33) that are soft and narrow. They are generally light yellow or yellow in color. The petioles of the affected leaves are too short. The affected plants neither produce any flowers nor set fruit. The roots of affected plants are also considerably stunted (Anupam Varma et al. 1975).

Management

- Choose tolerant or resistant cultivars available in the region. Varieties from India such as Pusa Purple Long, Pusa Purple Round, Pusa Purple Cluster, Nurki, Hisar Shyamal and H-10 have been reported to be tolerant or resistant (Sidhu and Dhatt 2007). Consult the local extension agency for the availability of tolerant or resistant varieties.

- Remove and destroy infected plants promptly to prevent the further spread of the disease.

Plate 33: Little leaf disease caused by phytoplasma, and vectored by *Hishimonus phycitis*

- Treat infected plants with tetracycline antibiotics.

- Spray a systemic pesticide in consultation with the local extension service to control the insect vector.

Integrated pest management approaches for insect and mite pests on eggplant

Cultural control

1. Avoid eggplant monocultures and follow crop rotations. As EFSB is practically a monophagous insect on eggplant, discontinuing eggplant cultivation in a community for few seasons will significantly reduce the population.

2. Avoid planting eggplant near cucurbits and cotton fields if thrips and aphids are common in the region.

3. Keep weeds under control in eggplant seedling production areas as well as in eggplant fields to reduce the availability of alternate host plants for some of the major insect pests.

4. Grow okra as a trap crop along the borders of eggplant field (Plate 34), and focus pesticide spraying on the okra trap crop to manage leafhoppers. Plant tall border crops like maize, sorghum, or pearl millet (Plate 35) to reduce the infestation of whiteflies.

5. Avoid ratoon cropping if stem borer is a serious problem in the region.

Host plant resistance

6. Choose resistant or tolerant cultivars for the major insect pests in consultation with the extension service.

Mechanical control

7. Do not raise eggplant seedlings near an existing or previous eggplant crop or heaps of dried eggplant stalks. If seedlings must be grown in those areas, cover the seedling

Plate 34: Trap cropping with okra to manage leafhoppers

Plate 35: Barrier cropping with maize to manage whitefly

Plate 36: Eggplant seedling production under net tunnel

beds with 30-mesh nylon net to prevent the entry of EFSB moths, which would lay eggs on the growing seedlings. If sucking insects such as whitefly and thrips are common in the region, use the 50–64 mesh nylon net to cover the seedling beds. Use seedling trays (Plate 37) under the net-tunnels or net-houses for seedling production.

8. Remove and destroy infested shoots (Plate 38) and fruit promptly at regular intervals until final harvest to manage EFSB. This will be highly effective when practiced throughout a community.

Behavioral control

9. To monitor insect populations, use yellow sticky traps (Plate 39) to attract whitefly and leafhoppers and blue sticky traps to attract thrips.

10. Use reflective plastic or straw mulches to reduce the incidence of whiteflies and thrips on eggplant crops.

Biological control

11. Apply neem formulations if recommended in the region, as soil drenches or through foliar application to control whitefly in eggplant seedling production.

12. Use neem-based biopesticides, which will not interfere with the activities of predators and parasitoids in eggplant production systems.

13. Apply neem cake to the soil to reduce the incidence of stem borer.

14. Install EFSB sex pheromone lures in traps (Plates 40-

Plate 37. Eggplant seedling production using trays under net house

Plate 38: Removal of EFSB infested shoots

Plate 39: Yellow sticky paper traps to monitor whitefly and leafhoppers

Plate 40: Sex pheromone traps to mass-trap EFSB moths — water trap

42) at the rate of 100 traps per hectare. Place the traps either at canopy level or at slightly above the canopy level for effective attraction. This will be highly effective when practiced in a community.

Chemical control

15. Do not spray any broad-spectrum pesticides against early season sucking pests. This may disrupt the complex of natural enemies in the ecosystem and lead to a resurgence of sucking pests. If necessary, use systemic pesticides recommended by the local extension service in the region. Do not use the same compound or pesticide group(s) continuously to reduce the development of pesticide resistance in insects.

Plate 41: Sex pheromone traps to mass-trap EFSB moths — funnel trap

Plate 42: Sex pheromone traps to mass-trap EFSB moths — winged trap

GLOSSARY

Acaricides	Pesticides that kill mites. They are also known as miticides
Atrophied	Diminution of a body part, organ or tissue
Axil	The angle between the petiole of a leaf and the stem or branch to which it is attached
Broad-spectrum pesticide	Non-selective pesticide that could kill wide range of species in an ecosystem
Canopy	Uppermost foliage cover in a plant or tree
Chlorophyll	Green pigment which gives green color to the leaves, stems, etc in the plant and is vital for photosynthesis
Cocoon	A pupal case, usually made up of silk
Cornicles	Paired tubular structures found at the posterior end of the abdomen. They are also known as siphunculi
Desiccate	Become dried
Deutonymph	The second nymphal stage in mites. Mostly, the deutonymph molts in to adult stage
Dorsum	Dorsum is the Latin word for the back. Back or top surface of insect body
Elytra (singular: **elytron**)	Heavily sclerotized and hardened forewing of coleopterans (beetles)

Excreta	Waste substances such as urine and faeces discharged from body
Exuvia (also **exuvium;** plural: **exuviae)**	Cast skin or shed skin after moulting
Frass	Mixture of chewed plant debris, faeces and other excretions
Honey dew	Liquid faeces of insects in the order Homoptera, containing soluble sugars and amino acids
Instar	Developmental stage during the larval period. The time interval between two subsequent molting is known as stadium. The form of an insect during any stadium is called as instar
Lacerate	To tear, torn or wound irregularly
Macrocyclic lactones	Products or their chemical derivatives of soil borne actinobacteria belonging to the genus, *Streptomyces*
Microtrichia	Minute hairs on the integument (insect skin)
Midrib	Prominent central vein in a leaf
Monoculture	Practice of cultivating a single crop on the same piece of land or in a region continuously

Monophagous	Feeding on only one species of host plant
Nymph	Larval stage in certain insect orders including hemiptera. Nymphs will directly develop into adults without undergoing pupal stage
Ocelli (singular: **ocellus)**	Simple eye with a lens and few photoreceptor cells
Oligophagous	Feeding on few related host plant species
Parasitoid	An organism which spends most of its life cycle within a single host insect for nutrients and protection and ultimately kills it
Parthenogenesis	A mode of reproduction in female insects in which growth and development of embryo occurs without fertilization by a male insect
Pesticide resistance	Inheritable tolerance to pesticides among pest populations of a species
Phytoplasma	A group of bacteria, which lacks cell wall and pleiomorphic or filamentous in shape. It is also known as mycoplasma like organisms or MLOs

Pleurotergite	The dorsal part of an insect body (especially thorax and abdomen) segment is known as tergum. A tergum may be made up of several plates, called tergites. Similar plates on the ventral part are called sternites. The sclerite in the lateral (pleural) part is known as pleurite. Thus, the pleurotergite is composed of a fused pleurite and tergite.
Polyphagous	Feeding on wide variety of host plant species
Protonymph	The first nymphal stage in mites
Puparium (plural: **puparia**)	The protective case covering the pupa in true flies (dipterans)
Ratoon crop	A second crop grown from the stubble of first crop after completing its final harvest
Setae (singular: **seta**)	Hair-like or bristle structures
Skeletonization	Process of destroying the tissues and leaving the basic structure or shape (of the leaves)
Solanaceous	Plant species in the family Solanaceae

Sooty mold	Black powdery coat on the leaf surfaces due to the growth of saprophytic fungi on the excretions (honey dew) of certain homopteran insects
Systemic pesticide	Pesticide that translocates throughout the plant system after application
Trichome	Hair like appendages on plant surfaces
Triungulin	First instar larva of insects in the family Meloidae, with three claws on each leg
Tubercles	Small, rounded, knob-like bumpy structures on the body of certain caterpillars. Sometimes they may also bear spines or hairs.
Viviparous	A mode of reproduction in which the embryo develops inside the body of the female and the mother gives birth to young ones

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