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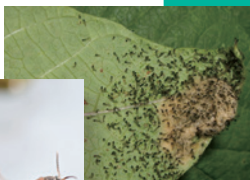
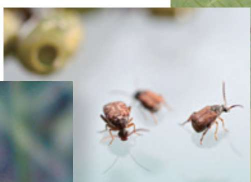
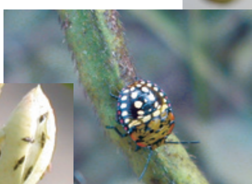
INSECT AND MITE PESTS ON VEGETABLE LEGUMES

A field guide for identification and management

R. SRINIVASAN







AVRDC – The World Vegetable Center

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

Legumes are one of the most important components of smallholder farming systems in tropical Asia, sub-Saharan Africa and Latin America. They are an important source of good quality dietary proteins. Legumes are also a good source of vitamins such as folate and dietary minerals like calcium, iron, magnesium and zinc. Antioxidants and other health-promoting substances in legumes also help to reduce the risks associated with some diseases such as cancer. Hence food legumes, especially vegetable legumes, are a boon to human health and are cultivated as valuable commercial crops, both for domestic and export markets.

Legumes are highly susceptible to several insect and mite pests in the tropics. Chemical pesticides are being predominantly used to manage these pests in South and Southeast Asia, as well as sub-Saharan Africa. In most countries, farmers apply pesticides over-intensively, with many of the pesticides used not being specifically appropriate for vegetable legume production. This leads to a substantial increase in production costs, besides posing serious health threats to farm laborers, producers, consumers and the overall condition of the environment.

AVRDC – The World Vegetable Center developed and validated an integrated pest management (IPM) strategy for vegetable legumes in Southeast Asia during the period 2010-2013. This IPM strategy is mainly based on the increased and more knowledgeable use of biopesticides and natural enemies and has thus reduced reliance on chemical pesticides. This strategy is currently being promoted in Southeast Asia, and is ready for broad-scale adoption in other major vegetable legume producing countries in the tropics.

This field guide contains pictures and information on major insect pests and mites damaging to vegetable legumes. Detailed information on IPM strategies to manage these pests in the tropics is also provided. This field guide has been prepared specifically for vegetable legume growers and extension specialists for whom I trust it will be of practical assistance to produce more wholesome and profitable vegetable legume crops in the future.

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INTRODUCTION

Vegetable legumes are important crops in Southeast Asia and sub-Saharan Africa. They are an important source of plant proteins in the human diet and are considered as "meat of the poor" (Heiser 1990). They are rich in essential micronutrients, especially iron and folic acid, which are particularly important for women of child-bearing age and other vulnerable groups. Leguminous crops fix atmospheric nitrogen in the soil, thus improving soil fertility. Legumes can be used as high quality livestock fodder, and are planted to control soil erosion.

Yard-long bean (*Vigna unguiculata* subsp. *sesquipedalis*) is the most popular vegetable legume in Southeast Asia (AVRDC 2001), accounting for almost 7% of the total vegetable production area in the region (Ali *et al*. 2002). It is cultivated on more than 130,000 ha in Indonesia, Thailand, and Vietnam (Benchasri and Bairaman 2010; Kuswanto and Budi Waluyo 2011). Other grain legumes are being cultivated on an area of 45 m ha in South and Southeast Asia (FAO 2012). Cowpea (*V. unguiculata*) and bean (*Phaseolus* spp.) are the two most important food legumes grown in Africa, occupying a total of about 19 m ha (FAO 2012). The seeds, tender leaves, and pods are consumed. Cowpea is among the top three or four leafy vegetables in several parts of Africa and the beans are also consumed (Pasquini *et al*. 2009; Weinberger and Pichop 2009). Cowpea leaves are consumed in 18 countries in Africa, and seven more in Asia and the Pacific, while bean leaves are consumed in at least eight African countries and Indonesia (Barrett 1990). Trading of fresh leaves and immature pods and processing cowpea into snacks provides opportunities for rural and urban women to earn cash in sub-Saharan Africa (Singh *et al*. 2003).

Vegetable legumes are highly susceptible to insect pests and diseases. Several insect pests including bean flies, aphids, thrips, leafhopper, whitefly, leaf beetles, pod borers, pod bugs and bruchid beetles cause significant damage to food legumes in the field or in storage. For instance, up to 80% yield losses have been reported in various vegetable and grain legumes due to legume pod borer damage in Asia and Africa (Singh *et al*. 1990; Afun *et al*. 1991; Dreyer *et al*. 1994; Ulrichs and Mewis 2004). At present, farmers rely almost exclusively on chemical insecticides to combat various insect pests, but without satisfactory control results. For example, more than 294,000 farmers used banned insecticides on cowpea in Benin (Pedune Benin 1999). Cambodian farmers sprayed up to 20 times per season with up to five different pesticides mixed together per tank per spray on major vegetables including yard-long bean (Sodavy *et al*. 2000). In Bangladesh, the country bean is being sprayed at weekly or biweekly intervals—sometimes every day—to control legume pod borer (Hoque *et al*. 2001). Sustainable pest management strategies offer a safe alternative to the misuse and overuse of pesticides on food legumes in tropical Asia and Africa.

This guide provides comprehensive information for vegetable and grain legume growers and extension staff about the major insect and mite pests on major food legumes and their management. The simple, low-cost integrated pest management (IPM) techniques outlined in this guide provide satisfactory, sustainable management and can help legume growers decrease their reliance on chemical pesticides. AVRDC – The World Vegetable Center has recently developed and successfully validated an IPM strategy for the management of legume pod borer and other major pests in Southeast Asia.

Insect and mite pests on vegetable legumes

Bean flies

Ophiomyia phaseoli Tryon, *O. centrosematis* de Meijere, *O. spencerella* Greathead, *Melanagromyza sojae* Zehntner, *M. obtusa* Malloch (Diptera: Agromyzidae)

Bean flies are one of the most destructive pests of food legumes, especially during the crops' seedling stage. They occur in Asia, Africa, Australia and Oceania. Larvae of these insects feed on legumes as internal feeders and leaf miners. *O. phaseoli* has the widest distribution and host range, and causes the maximum damage (Talekar 1990). Although the seasonal occurrence of *O. centrosematis* and the nature of damage it causes are similar to the predominant *O. phaseoli*, it is not perceived as a serious pest. *O. spencerella* is widespread in East Africa, and more dominant than *O. phaseoli* on beans (Sariah and Makundi 2007). *M. sojae* is a common pest of soybean in Asia, Australia and occasionally in Africa (Talekar 1990). *M. obtusa* is a key pest of pigeon pea throughout South and Southeast Asia (Shanower *et al*. 1998).

Biology

Egg: The adult females of *O. phaseoli* lay eggs in unifoliate or early defoliate leaves. A biotype of *O. phaseoli* in Indonesia and Taiwan was found to lay eggs only in the cotyledon of the newly germinated soybean plant (Talekar and Chen 1985). They usually lay the eggs on the upper leaf surfaces, often near the midrib close to the petiole. The eggs are inserted between the epidermis and spongy parenchyma (Talekar 1990). The egg is oval shaped, milky white in color and opaque or translucent. Each female lays about 300 eggs throughout its life. The egg period is 2 to 4 days depending on the temperature. The egg laying behavior of *O. spencerella* is similar to *O. phaseoli*. Its oviposition mainly occurs in the hypocotyl at ground level during the first week of germination. Sometimes the eggs are laid on the young stem tissue above the cotyledons (Talekar 1990). *O. centrosematis* lays eggs just underneath the epidermis in the hypocotyl of young seedlings. On average, a single female lays 50-75 eggs in her lifetime (Talekar and Lee 1988). The egg-laying behavior of *M. sojae* is similar to *O. phaseoli*. However, egg laying normally occurs at the basal part of the leaf lamina, near the petiole. The eggs are laid singly, are white in color and partly transparent. The egg period is 2 to 3 days. *M. obtusa* lays eggs singly on the green pods. The freshly laid eggs are white and broad. The egg period is 3 to 10 days depending on the temperature (Talekar 1990).

<u>Maggot</u>: The larva of *O. phaseoli* has three instars. The newly hatched pale larvae remain motionless beneath the leaf epidermis in a cavity made by its mother during egg laying. One to two hours after emergence, it starts feeding inside a mine directed toward the vein of the leaf. On reaching the midrib, the larva constructs a tunnel in it and molts into the second instar. The yellowish white second instar larva moves its head constantly from side to side within the relatively straight mine built in the leaf vein. The light yellow-colored third instar larva actively feeds in the petiole or stem. In younger plants, the larva continues feeding inside the stem until or slightly below the soil level. However, it feeds only in the junction of petiole and stem until its pupation in older plants (Talekar 1990). The larval period is about 8 to 9 days. The larva of *O. spencerella* from eggs laid on leaves follow a lifecycle similar to *O. phaseoli*. The larva from eggs laid in the hypocotyl or stem feeds in the hypocotyl and roots. The larva of *O. centrosematis* also has three instars that

last for 11 to 13 days (Talekar and Lee 1988). The young larva of *M. sojae* is colorless; it is difficult to see them when the stem is cut open. *M. sojae* larva also has three instars, and the larval period is 7 to 14 days depending on the temperature. The freshly hatched larva of *M. obtusa* is white with dark brown or black mouth parts. The fully grown larva is sub-cylindrical, creamy white with dark black mouth parts (Plate 1). The body acquires a yellow tinge just before pupation. The larval period varies from 6 to 19 days depending on the temperature (Talekar 1990)

<u>Pupa</u>: The larva of *O. phaseoli* pupates on young plants beneath the epidermis of the stem near the soil surface. Under high larval density, pupation may also take place inside the stem pith (Plate 2). In mature plants, pupation takes place at the junction of the leaf lamina and petiole. The pupa is yellow with a brownish tinge and is barrel shaped (Plate 3). The color of the puparium becomes dark brown shortly before adult emergence (Talekar 1990). The pupal period varies from one to three weeks depending on the temperature and altitude. The pupation in *O. spencerella* is similar to *O. phaseoli*. *O. centrosematis* pupates in the cortex just below the epidermis at the root junction. Pupa is light yellow soon after pupation; it gradually turns to golden yellow and dark yellow toward adult emergence. The pupal period is about 10-13 days (Talekar and Lee 1988). The pupa of *M. sojae* is cylindrical and golden yellow in color. It mostly pupates in the pith tunnel. The pupal period varies from 6 to 12 days. The larva of *M. obtusa* briefly enters into a pre-pupal stage (Singh 1982). The pupa is enclosed in a hard chitinous puparium that is attached to the inner side of the pod wall. The newly formed pupa is yellowish white and gradually turns to creamy yellow, reddish brown and darker (Talekar 1990). The pupal period varies from 1 to 3 weeks.

Adult: The adult *O. phaseoli* flies are metallic black in color, with light brown eyes and hyaline wings having a distinct notch in the coastal region. The longevity of adults could be as high as 1.5 months, with an average of 3 weeks. However, the copulating male usually lives for about 10 days, and the egg laying female lives for 1 to 3 weeks. *O. spencerella* adults are small and brilliant shiny black, generally resembling *O. phaseoli*. *O. centrosematis* is also a small, black fly. Adult males live for about 10 to 20 days, whereas females live for 9 to 13 days. The *M. sojae* adult is also metallic black in color, and it is a weak flier. The mean life span is about 3 to 4 weeks. The newly emerged adult of *M. obtusa* is dull white and changes to black in an hour (Talekar 1990). The life span is only 7 to 12 days.

Damage symptoms

The most serious damage by *O. phaseoli* adults starts at the unifoliate leaf stage. The unifoliate leaves show several feeding and oviposition punctures on the upper surface with corresponding light yellow spots, especially in the basal portion of the leaf. These feeding and oviposition wounds could predispose the plant for the entry of pathogens. The larvae start feeding in the leaf tissue, leaf lamina and then the petiole and stem. The larvae feed voraciously in the cortex, and continue downwards into the tap root. Because of the severe disturbances in the transport of water and nutrients, the plants, especially in the seedling stage, wilt and die (Plate 4). If the infestation starts in the later plant growth stages, the damage is limited to the leaf petioles, but not to the stem. The damage to the petiole leads to wilting of the leaves. Even stem damage at this stage may not result in plant mortality, but leads to stem swelling. *O. spencerella* also causes damage similar to

Plate 1: Bean fly - maggot

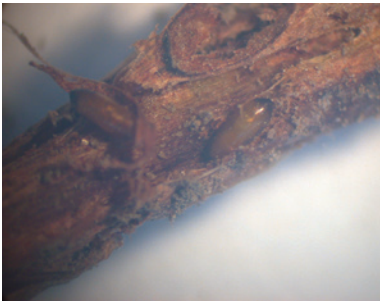


Plate 2: Bean fly – pupation in stem pith

Plate 3: Bean fly - pupa

Plate 4: Legume seedling damaged by bean fly

O. phaseoli. *O. centrosematis* usually does not cause significant damage. The larva feeds inside the stem by tunneling that leads to weakening, and sometimes death of the plants (Talekar 1990).

Soon after emergence, the larva of *M. sojae* burrows through the mesophyll tissue into the closest vein moving downward in the leaf. Through the leaf vein and then the petiole, the larva continues feeding downwards into the stem and makes a tunnel into the pith, reaching the stem-root junction. It bores a little further into the thickened main root and moves upwards, thus widening the original tunnel (Talekar 1990).

The young larvae of *M. obtusa* attach themselves to the soft seeds inside the pods, and initially feed on the seed surface. They subsequently mine into the seeds, and the mines are often filled with fecal matter. Older larvae feed deep into the seeds, at times eating the embryo. Usually, a larva completes its development in one seed. The fully grown larvae come out of the seed, leaving behind a clear exit hole (Talekar 1990). Thus, the damaged pod is poorly filled.

Management

1. Choose resistant or moderately resistant cultivars available in the region. For instance, accessions or varieties having purple stems, thinner stems and smaller pith diameter are resistant to bean flies (AVRDC 1990; Talekar 1990). AVRDC soybean accessions (G11569, PI171444 and PI227687), mungbean accessions (V4281 and one of its progenies, VC4035-17), *Vigna glabrescens* accession (V1160) and *V. sublobata* were found to be resistant to *O. phaseoli*, *O. centrosematis* and *M. sojae* (AVRDC 1987; 1990;

1991; 1992). Consult the local extension agency for availability of resistant or tolerant varieties.

2. Earth up the plants three days after the appearance of the cotyledons above ground, so that most of the plants can overcome bean fly infestation. Production of adventitious roots in the affected basal portion of the stem helps considerably in the resistance of the plant (Talekar 1990).
3. Although intercropping is not highly useful in reducing bean fly incidence, intercropping jute with mungbean simultaneously in alternate rows could reduce the bean fly infestation (AVRDC 1981 a&b). Growing pearl millet and mungbean as intercrops with pigeon pea reduce the damage of *M. obtusa* (Talekar 1990). Cultivation of onion as an intercrop with common bean (*Phaseolus vulgaris*) lowers bean fly infestation (Jemutai 2008).
4. Moth bean, chickpea, lentil, and cluster bean could be used as 'dead-end trap crops'—the bean fly adults lay eggs on these crops, but the eggs fail to hatch (Talekar and Lee 1988).
5. Plant late-maturing soybean varieties to reduce the yield losses due to *M. sojae* (AVRDC 1986). Early sowing of bean crops in Tanzania helps reduce bean fly infestations (Sariah and Makundi 2007).
6. Parasitoids such as *Opius phaseoli* Fischer against *O. phaseoli* and *Eucoilidea* sp. against *O. spencerella* and *O. centrosematis* are efficient parasitoids (Abate and Ampofo 1996). Protect the population of these parasitoids by avoiding the use of broad-spectrum pesticides.
7. Effective seed-dressing insecticides have been identified (Abate and Ampofo 1996; Jemutai 2008). Consult the local extension agency for appropriate local recommendations.

Cowpea aphid

Aphis craccivora Koch

(Hemiptera: Aphididae)

This is a serious pest on cowpea, yard-long bean, hyacinth bean and peanut starting from the seedling stage to pod-producing stage. It acts as a direct pest and also transmits virus diseases. Although this aphid remains active throughout the year, it causes severe damage during the cool dry season.

Biology

Adult: Unlike many insects, most aphids reproduce asexually in the tropics. They usually reproduce through parthenogenesis (development of embryo without mating with males) and are viviparous (give birth to nymphs directly rather than eggs). The early instar nymphs are grey in color, whereas the late instar nymphs and adult are black. Both wingless and winged forms occur. Winged forms are produced when population density is high, when host plants are of inferior quality, etc. The wingless forms (Plate 5) are more common. Aphids mostly are found in groups. The nymphal period is about 5 to 8 days, and the total lifecycle is 11 to 14 days.

Damage symptoms

A. craccivora prefers to feed on legume crops; it is commonly known as "cowpea aphid." Both the nymphs and adults possess piercing and sucking mouthparts. They occur in large numbers on the tender shoots, lower leaf surfaces, petioles, flowers and pods, and suck the plant sap. Slightly infested leaves exhibit yellowing. Severe aphid infestations cause stunting, crinkling and curling of leaves, delayed flowering, shriveling of pods (Plate 6), resulting in yield reduction. Young plants may be killed due to heavy infestation. *A. craccivora* also transmits

Bean common mosaic virus and *Cucumber mosaic virus* in a non-persistent manner (Damayanti *et al*. 2009). Large populations of the pest secrete substantial quantities of honeydew (Plate 7), which favors the growth of sooty mold (Plate 8) on leaves and reduces the photosynthetic efficiency of the plants.

Plate 5: *Aphis craccivora* - adults

Plate 6: *Aphis craccivora* – damage

Plate 7: *Aphis craccivora* – honeydew secretion

Plate 8: *Aphis craccivora* – sooty mold

Management

1. Avoid monoculture and follow crop rotation. The selected field should be located away from other legume crops.
2. Use entomopathogenic fungi (EPF) such as B*eauveria bassiana*, *Metarhizium anisopliae*, *Verticillium lecanii* and *Hirsutella thompsonii* at a concentration of 1×10^8 conidia ml^{-1} (Ekesi *et al*. 2000; Saranya *et al*. 2010).
3. Use neem oil, either alone or in combination with the EPF biopesticides (El-Hawary and Abd El-Salam 2008; Halder *et al*. 2013).
4. The ladybird beetles (*Menochilus sexmaculatus, Brumus suturalis, Harmonia dimidiate*, *Brumus suturalis* and *Coccinella septempunctata*) and green lacewings (*Chrysoperla carnea*) are efficient predators of aphids (Muniappan *et al*. 2012). Protect the population of these predators by avoiding the use of broad-spectrum pesticides.
5. *A. craccivora* can develop resistance to pesticides (Mokbel and Mohamed 2009). Use only those pesticides that have been recommended by local extension staff. Do not use the same compound or pesticide group continuously to avoid the development of pesticide resistance in insects.

Whitefly
Bemisia tabaci Gennadius
(Hemiptera: Aleyrodidae)

The whitefly is widely distributed in tropical and sub-tropical regions. *B. tabaci* is highly polyphagous and is known to feed on several vegetables including legumes, tomato, eggplant and okra, field crops and weeds. Hot and dry conditions favor the whitefly, and 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 9). The eggs are not visible to the naked eye, and must be observed under a magnifying lens or microscope. Egg period is about 3 to 5 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. 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 atrophied during the next three instars and they are immobile during the remaining nymphal stages. The last nymphal stage has red eyes (Plate 10). This stage is sometimes referred to as 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 11). 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. Adult males are slightly smaller in size than females. Adults live from 1 to 3 weeks.

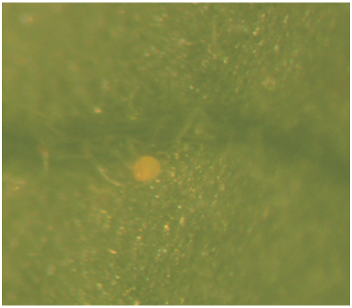


Plate 9: *Bemisia tabaci* - egg

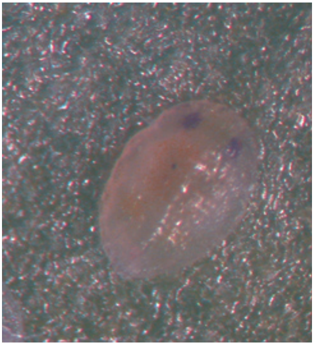


Plate 10: Red-eyed nymph of *Bemisia tabaci*

Plate 11: *Bemisia tabaci* - adult

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. Large populations (Plate 12) secrete substantial quantities of honeydew, which favors the growth of sooty mold on leaf surfaces and reduces the photosynthetic efficiency of the plants. If the infestation occurs during the pod formation stage, infected pods turn yellow and produce shriveled grains. In addition to direct damage, *B. tabaci* also acts as a vector for several viral diseases including *Mungbean yellow mosaic virus* (MYMV), *Cowpea mild mottle virus* (CPMMV), and *Bean golden yellow mosaic virus* (BGYMV) on crops such as mungbean, yard-long bean, common bean, cowpea and soybean (Mink and Keswani 1987; Bob *et al*. 2005; Morales *et al*. 2005; Brito *et al*. 2012).

Plate 12: Crowding of *Bemisia tabaci*

Management

1. Whitefly is a polyphagous insect; it has several host plants for feeding and survival ranging from cultivated crops to weeds. The field selected for vegetable legumes should be clean and not be located near any host plants and weeds.
2. Use of MYMV resistant or tolerant varieties is suggested to overcome the disease. For example,

mungbean varieties ML 267, ML 613, NM 92 and VC 6372 (45-8-1) are found to be consistently resistant to MYMV across many locations (Shanmugasundaram *et al*. 2009). Mungbean genotypes such as ML 508, ML 537, ML 395, ML 505, and ML 543 are reported to be resistant against *B. tabaci* and MYMV (Chhabra and Kooner 1994a; Kooner 1998).

3. Grow seedlings for crops such as yard-long bean in insect-proof (50–64 mesh) net houses, net tunnels, greenhouses, or plastic houses.
4. 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.
5. Maintain a high standard of weed control in seedling production areas and crop fields to reduce the availability of alternate host plants.
6. 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 and yellow plastic or straw mulches may reduce landing of whiteflies.
7. Neem formulations (if available) can be applied as a soil drench or foliar application to control whitefly in vegetable legume seedlings. Seed treatment with neonicotinoid pesticide formulations (if available) also reduces whitefly populations and incidence of MYMV disease (Salam *et al*. 2009).
8. Natural enemies such as *Encarsia sophia* and *E. formosa* are efficient parasitoids of whiteflies (Bob *et al*. 2005). Protect the population of these parasitoids by avoiding the use of broad-spectrum pesticides.
9. 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.

Leafhoppers

Empoasca kerri Puthi, *E. facialis* Jacobi, *E. fabae* Harri

(Homoptera: Cicadellidae)

E. kerri occurs mainly in Asia, whereas *E. facialis* occurs in Africa and *E. fabae* is widespread in Americas (Ranga Rao *et al*. 2013). The relatively dry and humid weather conditions generally favor the population build-up of leafhoppers.

Biology

Egg: The adult females lay eggs along the midrib and lateral veins of the leaves, or into the petiole. The eggs are not visible to the naked eye. The egg period is about one week.

Nymph: The nymphs resemble the adults, but lack wings. 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 2 to 3 weeks, depending on the temperature.

Adult: The adults are wedge-shaped, pale green insects (Plate 13). They have fully developed wings, and are about 2.5 mm long.

Plate 13: *Empoasca* spp. - adult

Damage symptoms

Both nymphs and adults suck the sap from the lower leaf surfaces through their piercing and sucking mouthparts, 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 (becoming reddish-brown) (Plate 14) and drying. Leafhoppers also cause similar damage in cotton and potato.

Plate 14: *Empoasca* spp. – damage (bronzing)

Management

1. Monitor the insects with yellow (570-580 nm) sticky traps placed at random in the field.
2. Okra, sesame, sorghum and pearl millet can be grown as inter-crops in vegetable legume (*e.g.*, mungbean) fields. This reduces the leafhopper damage significantly (Chakravorty and Yadav 2013).
3. Avoid the use of broad-spectrum pesticides to encourage the performance of natural enemies. Generalist predators such as ladybird beetles and green lacewings are efficient in preying on leafhopper nymphs and adults.
4. Use neem-based biopesticides at recommended doses. If the commercial neem formulations are not available, neem seed kernel extract (NSKE) @ 5% can also be sprayed.
5. 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.

Common armyworm

Spodoptera litura Fabricius

(Lepidoptera: Noctuidae)

S. litura is a polyphagous and highly mobile insect and it is a pest of economic importance on many agricultural and horticultural crops. It is the predominant species on several vegetable legumes in tropical South and Southeast Asia. As they are nocturnal, the larvae feed actively during night hours. During the day, the larvae hide under soil cracks and crevices or plant debris in the field.

Biology

Egg: The eggs are laid in groups of 200–300, and covered with brown hairs from the body of the mother (Plate 15). The egg period is about 3 to 5 days.

Larvae: Upon hatching, the neonate larvae are translucent green with dark thorax and gregarious (Plate 16). The young larvae remain and feed in groups. However, they disperse when they grow older to feed individually. The grown-up larvae are green to pale greenish brown or black in color; they have stout, cylindrical bodies with prominent black spiracles (Plate 17). The body may have transverse and longitudinal grey and yellow bands. Mature larvae can grow to about 35–40 mm in length. When disturbed, the larvae curl into a 'C' shape with the head kept at the center. Larval period is about 15 to 30 days. The larva passes through six instars.

Pupa: Pupation takes place in the soil. Pupae are shiny reddish brown. The pupal period varies from 1 to 3 weeks.
Adult: The adult is a stout bodied moth (Plate 18) with a wing span of about 40 mm. The adults are usually brown

colored; the forewings have numerous criss-cross streaks in a cream or brown background. The hind wings are white with a brown patch along the border. The eighth abdominal segment of female moths possesses dense scales.

Plate 15: *Spodoptera litura* - egg mass

Plate 16: *Spodoptera litura* - early larvae in group

Plate 17: *Spodoptera litura* - grown-up larva

Plate 18: *Spodoptera litura* - adult

Damage symptoms

The neonate larvae feed on leaf surfaces and cause skeletonization, leaving behind the whitish membranous leaves only (Plate 19). Mature larvae feed on the whole leaves until only main veins are left. Sometimes, the larvae may also cut the seedlings or young plants at soil level, which may lead to complete destruction of the crop.

Plate 19: *Spodoptera litura* – damage (skeletonization)

Management

1. Castor (*Ricinus communis* L.) can be grown as a trap crop along the field border to attract egg-laying female adult moths. As eggs will be laid in masses, the egg masses and young larvae that still remain and feed in groups can be hand-picked and destroyed either on the trap crop or on the main crop.

2. Sex pheromones of *S. litura* are commercially available in many countries and can be used for monitoring as well as mass-trapping.
3. *Spodoptera litura* nucleopolyhedrovirus (SlNPV) is commercially available in some countries, and can be used to replace chemical pesticides. SlNPV is effective either alone or in combination with neem (Prasad and Wadhwani 2006). In addition, *Bacillus thuringiensis* formulations can be used to manage *S. litura* (Sharma *et al*. 2011).
4. The egg-parasitoids (*e.g.*, *Trichogramma chilonis* Ishii) and larval parasitoids (*e.g.*, *Campoletis chlorideae* Uchida) can be conserved and/or released (Bajpai *et al*. 2006) in vegetable legume fields at regular intervals to check the build-up of *S. litura*. If the natural enemies such as parasitoids and predators are present in the field, avoid using broad-spectrum chemical pesticides that are lethal to these natural enemies (Md. Abdullah *et al*. 2001). Instead, botanical pesticides such as neem that are safer for the parasitoids (Maria Packiam and Ignacimuthu 2012) can be used to augment the natural enemies.
5. Chemical pesticides can be applied as needed. Chemical pesticides may highly be effective against early larval stages, when the larvae remain in groups. Consult the local extension agency for appropriate recommendations.

Beet army worm
Spodoptera exigua Hubner
(Lepidoptera: Noctuidae)

Like *S. litura, S. exigua* is also a polyphagous and nocturnal insect that mainly feeds on vegetable soybean, besides other vegetables such as tomato, eggplant, hot and sweet pepper, onion, etc.

Biology

Egg: The eggs are laid in groups of 100–150 and covered with brown hairs from the body of the mother, similar to *S. litura*. The egg period is about 3 to 5 days.

Larva: The grown-up larvae are brownish green dorsally and pale yellow colored ventrally with a lateral white or yellow stripe (Plate 20). Larval period is about 2 to 3 weeks. The larva passes through five instars.

Pupa: Pupation takes place in earthen cocoons in soil. Pupae are light brown. The pupal period varies from 7 to 11 days.

Adult: Adults of *S. exigua* are medium-sized moths with a wing span of about 30 mm. The adults are usually brown colored; the forewings are mottled brown in color. The hind wings are grey with a brown line along the border. The adult period is about 10 days, and on average a single female lays about 500–600 eggs.

Damage symptoms

The larvae cause defoliation. Sometimes, the larvae may also cut the seedlings or young plants at soil level. Occasionally the larvae may feed on the pods.

Management

Similar to *S. litura*.

Plate 20: *Spodoptera exigua* - larva

Bean foliage beetles
Ootheca spp.
(Coleoptera: Chrysomelidae)

Ootheca mutabilis (Schönherr) and *O. bennigseni* Weise are important foliage feeders on food legumes such as cowpea and common bean in eastern and southern African countries, especially Burundi, Kenya, Rwanda, Tanzania and Zambia (Abate and Ampofo 1996). They attack the foliage soon after germination, causing yield losses of 27-100% (Singh and Allen 1980; Raheja 1981).

Biology
Egg: The females lay eggs in clusters of about 60 eggs per cluster in soil close to the legume plants. Each female lays up to eight egg clusters. The eggs are elliptical and yellow in color. The egg period is about 2 to 3 weeks.

Larva: The larva of *Ootheca* spp. develops through three instars, followed by a pre-pupal stage. The larval period varies from 5 to 11 weeks depending on the temperature.

Pupa: The larva pupates in an earthen cell within the soil. The pupal stage lasts for about 16 days. Soil temperature plays an important role in its development.

Adult: The adults of *Ootheca* spp. undergo an obligatory diapause until the onset of the rainy season. The adult beetles are shiny, oval shaped and about 6 mm long (Plate 21). The adults vary in color ranging from orange to brown, and at times blackish.

Plate 21: Adult of *Ootheca* spp.

Damage symptoms

The adult beetles start feeding on leaves of newly planted legume crops, especially cowpea and beans. They feed on the foliage between the veins, and cause extensive defoliation. Damage to the growing shoots of young seedlings and heavy infestation completely destroy a crop. The adults occasionally feed on the floral parts. Additionally, larvae feeding on lateral roots cause wilting and premature senescence in bean plants (Abate and Ampofo 1996). Apart from direct feeding, the beetles also vector *Cowpea yellow mosaic virus* (Robertson 1963).

Management

1. Choose tolerant or resistant cultivars available in the region. For instance, several bean lines are reported to be moderately resistant to *O. bennigseni* in Tanzania (Karel and Rweyemamu 1985). Consult the local extension agency for the availability of tolerant or resistant varieties.

2. Biopesticides such as neem are highly effective against *Ootheca* spp. Use biopesticides if they are available and recommended in the region.
3. Locally prepared botanical extracts such as aqueous extract from vernonia (*Vernonia lasiopus* var. *iodocalyx*) leaves are proven effective in reducing the infestation of *Ootheca* spp. (Paul *et al*. 2007).
4. Do not control the *Ootheca* infestation with broad-spectrum chemical pesticides. If necessary, spray a recommended pesticide after consulting with local extension staff.

Thrips

Megalurothrips distalis Kany, *M. usitatus* (Bagnall), *M. sjostedti* (Tribom)

(Thysanoptera: Thripidae)

M. distalis and *M. usitatus* are widely distributed in South and Southeast Asia and Oceania; *M. sjostedti* predominantly occurs in Africa. They mainly feed on the flowers of legumes, and can cause 100% yield losses if left uncontrolled.

Biology

Egg: The females lay eggs within the leaf tissues, especially in the terminal leaflets. The egg may not be visible to the naked eye. The egg period is about 2 to 3 days.

Larva: The larva of *M. distalis* is whitish translucent. *M. usitatus* larva is pale yellow in color, and turns to yellowish to orange-red, whereas the larva of *M. sjostedti* is whitish in the beginning and later turns to yellow to orange. The larval period varies from 1 to 2 weeks depending on the temperature. As pupation nears, the larva stops feeding and moves down to the soil surface either in the soil or under plant debris.

Pupa: The pupal stage lasts for five days to one week. Moisture plays an important role, because dryness in the soil could lead to the desiccation and death of the pupae.

Adult: The adults of *M. distalis* are brownish in color, whereas the adults of *M. usitatus* are dark brown (Plate 22). The adults of *M. sjostedti* are black in color. The adults of *Megalurothrips* are about 1.5-1.65 mm long.

It is very difficult to confirm the exact identity of thrips with the naked eye; they must be identified under microscopes in laboratory conditions. Adults live from 1 to 3 weeks.

Plate 22: Adult of *M. usitatus*

Damage symptoms

Thrips remain hidden inside the flower buds and flowers. Both the larvae and adults feed on the tender leaves in the beginning. However, they prefer to feed mostly on flowers (inflorescence). Slightly infested leaves exhibit silvery feeding scars. In severe infestations on the flowers, the open flowers are discolored and distorted showing elongated brownish streaks; they dry out, and fall prematurely without forming pods. Infested pods are scarred and deformed.

Management

1. Choose tolerant or resistant cultivars available in the region. For instance, mungbean lines SML 99, SML 100, SML 103, SML 112 and SML 117 are reported to be resistant to *M. distalis* (Chhabra and Kooner 1994b). Consult the local extension agency for the availability of tolerant or resistant varieties.
2. Grow vegetable legume (*e.g.*, yard-long bean and common bean) seedlings in insect-proof (50–64 mesh) net houses, net tunnels, greenhouses, or plastic houses to avoid early infestation, especially in the dry season.
3. Predators such as *Orius albidipennis* and *Paederus sabaeus* feed on *M. sjostedti* in West Africa (Tamo *et al*. 1993). Parasitoids such as *Ceranisus menes* Walker and *C. femoratus* Gahan (Hymenoptera: Eulophidae) are effective candidates against *M. sjostedti* and *M. usitatus* (Chang 1990; Tamo *et al*. 2012). 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.
4. Entomopathogenic fungi could play a vital role in managing bean flower thrips, because of the moisture and humidity within the flower buds. For instance, 100% mortality of the adults of *M. sjostedti* was recorded at the highest concentration ($1{\times}10^8$ conidia ml^{-1}) of *Metarhizium anisopliae* at 8 days post-inoculation. At the same concentration, daily pollen consumption was significantly reduced at 2 days after treatment in infected adults (Ekesi and Maniania 2000).

5. Use mulch and reflective materials in vegetable legume fields to reduce the incidence of thrips.
6. Do not control the thrips infestation with broad-spectrum chemical pesticides, as a resurgence of thrips will likely occur. If necessary, spray a systemic pesticide after consulting with local extension staff.

Pod bugs

Clavigralla gibbosa Spinola, *C. scutellaris* (Westwood), *C. tomentosicollis* (Stal.)

(Hemiptera: Coreidae)

C. gibbosa and *C. scutellaris* are distributed in the tropics and sub-tropics, whereas *C. tomentosicollis* is predominantly present in Africa. They mainly feed on vegetable and grain legumes. These bugs comprise a serious group of pests causing damage to food legumes. They can cause yield loss of 20-100% in different parts of Asia and Africa.

Biology

Egg: The females lay eggs mostly on the leaves and pods. On average, each *C. gibbosa* and *C. scutellaris* female lays about 60-200 eggs, whereas *C. tomentosicollis* lays about 120 eggs. The egg is brown in color. *C. scutellaris* eggs are smooth and shiny, and the eggs of *C. gibbosa* are roughly sculptured. Eggs are laid in clusters of 2-60. *C. gibbosa* generally lays clusters of 3-15 eggs, whereas *C. scutellaris* lays clusters of 18-20. The egg period varies from 2 to 5 days. However, it may be prolonged up to three weeks under low temperature conditions.

Nymph: The newly hatched nymphs of *Clavigralla* are reddish in color and later turn brown. Nymphs are gregarious. The nymphal period is about 1 to 3 weeks, depending on the temperature.

Adult: The *Clavigralla* bugs are brown-gray in color (Plate 23). In the field, *C. gibbosa* and *C. scuttellaris* are often mistaken for each other. However, *C. scutellaris* is more robust (about 12 mm long) than *C. gibbosa* and *C. tomentosicollis* (about 10 mm long). The adult longevity is more than three months for the *Clavigralla* bugs (Ranga Rao *et al*. 2013). Although the males and females are similar, the female is slightly larger with a rounded abdomen.

Plate 23: *Clavigralla* bugs - adult

Damage symptoms

The nymphs and adults have piercing and sucking mouthparts. They penetrate the pod walls and suck the sap from developing seeds inside. Occasionally they also feed on stems, leaves and flower buds. Feeding on the pods causes yellow blotches. Severe infestations lead to shriveled pods and seeds. The damage is serious during prolonged dry weather conditions.

Management

1. Inter-cropping of legumes with millets such as sorghum could delay the infestation of pod bugs.
2. Parasitoids such as *Gryon fulviventris* (Crawford) (Hymenoptera: Scelionidae) against *C. tomentosicollis* in Africa, an unidentified *Gryon* sp. against *C. gibbosa*, and *Gryon clavigrallae* Mineo against *C. gibbosa* and *C. scutellaris* in Asia are found to be effective candidates for biological control (Bhagawat *et al*. 1994; Asante *et al*. 2000; Romeis *et al*. 2000). If the parasitoids are present in the field, avoid using broad-spectrum chemical pesticides that would be lethal to these natural enemies.
3. Entomopathogenic fungi could play a vital role in managing the *Clavigralla* bugs. For instance, high mortality of the adults of *C. tomentosicollis* was recorded when they were treated with *M. anisopliae* CPD 5 and *Beauveria bassiana* CPD 9 strains at 7 days post-inoculation (Ekesi 1999).
4. Do not spray broad-spectrum chemical pesticides. If necessary, spray a systemic pesticide after consulting with local extension staff.

Bean bugs

Riptortus pedestris (F.), *R. clavatus* (Thunberg)

(Hemiptera: Alydidae)

Bean bugs are serious pests of food legumes and they feed mainly on soybean. They occur in South and Southeast Asia including Japan, Korea and Taiwan. They can cause significant reduction in pod and grain yields and quality.

Biology

Egg: The females lay single eggs mostly on the bases of younger flowers and pods. On average, each female lays about 115 eggs. The egg period is 3 to 5 days.

Nymph: The nymphs are brownish black and hemispherical, resembling brown ants. The nymphal period is 2 to 3 weeks, and the nymphal stage is made up of five instars.

Adult: The *Riptortus* bugs are slender and longer (about 18 mm) than *Clavigralla* bugs, and brown in color (Plate 24).

Plate 24: *Riptortus* bugs - adult

Damage symptoms

The damage symptoms are similar to *Clavigralla* bugs.

Management

1. Delayed sowing from normal planting season of legumes helps avoid damage from bean bugs due to lower pest densities (Wada *et al*. 2006).
2. Parasitoids such as *Gryon japonicum* (Ashead), *G. nigricorne* (Dodd), *Ooencyrtus nezarae* (Ishii), and *O. acastus* (Trjapitzin) are the major egg parasitoids of *Riptortus* bugs, and are effective candidates for biological control in Asia (Youn and Jung 2008). If the parasitoids are present in the field, avoid using broad-spectrum chemical pesticides that would be lethal to these natural enemies.
3. Inter-cropping of legumes (e.g. soybean) with trap crops (e.g. sesame and corn) can enhance the performance of parasitoids such as *G. japonicum* and *O. nezarae* and thus reduce the infestation of *Riptortus* bugs (Youn and Jung 2008).
4. Aggregation pheromones produced by the males of *R. pedestris* attract the adults and nymphs (Paik *et al*. 2009). Use synthetic aggregation pheromones of *R. pedestris*, if available.
5. Aggregation pheromones of *R. pedestris* also attract the egg parasitoid *O. nezarae*. Combined deployment of aggregation pheromone traps and non-viable eggs of *R. pedestris* for field multiplication of the parasitoid enhances the suppression of *R. pedestris* (Alim and Lim 2011).
6. Entomopathogenic fungi such as *B. bassiana* could be used to manage *Riptortus* bugs (AVRDC 1992).
7. Do not spray broad-spectrum chemical pesticides. If necessary, spray a systemic pesticide after consulting with local extension staff.

Southern green stink bug
Nezara viridula (L.)
(Hemiptera: Pentatomidae)

N. viridula is a cosmopolitan and highly polyphagous pest species feeding on 30 plant families (Todd 1989). Although it causes economic damage to many crop species, it mainly feeds on legumes.

Biology

Egg: The barrel-shaped eggs are laid in clusters of 80-100 on the lower leaf surfaces and pods, in the upper regions of the crop. The eggs turn to deep yellow and finally reddish a few days before hatching. The egg period varies from 5 to 10 days.

Nymph: The newly hatched nymphs remain in groups near the egg-shells for a day or two and they do not feed. Although the second instar nymphs start feeding, they remain in groups until the third instar. The brightly colored nymphs (Plate 25) develop through five instars and the larval period is about 3 to 7 weeks, depending on the temperature.

Adult: Although the nymphs are brightly colored with multiple color patterns, the adult is green (Plate 26). Adults live up to three weeks in hot summer weather, but they live longer over winter. In regions with a cold winter, the autumn generation will overwinter or diapause (Knight and Gurr 2007). Most diapausing adults turn to a reddish brown color. The adult is about 15 mm long.

Plate 25: *Nezara viridula* – nymph

Plate 26: *Nezara viridula* – adult

Damage symptoms

The damage symptoms are similar to other pod bugs, causing drying of shoots (Plate 27), shriveled pods and seeds. In addition, the bugs may carry the spores of fungal pathogens from plant to plant, and mechanically transmit plant pathogens while feeding (Muniappan *et al*. 2012).

Plate 27: Nezara viridula – damage by nymphs

Management

1. Early maturing legume crops could be used as a trap crop for *N. viridula*. However, adults of *N. viridula* will quickly move from the trap crop to the main crop if they are at more attractive stages. Hence, chemical control of early instar *N. viridula* in trap crops is necessary to prevent movement into the main crop (McPherson and Newsom 1984).

2. Egg parasitoids such as *Ooencyrtus malayensis* (Ferriere), *Trissolcus basalis* Wollaston, *T. rudus* Le Xuan Hue, *T. mitsukurii* (Ashmead), *T. nakagawai* Watanabe, *Telenomus cyrus* (Nixon), *T. pacificus* (Gahan) and *T. comperei* Crawford are found in different countries in South and Southeast Asia (Muniappan *et al*. 2012). The Reduviid predator, *Sycanus collaris* Fab., also keeps this pest under control. Avoid using broad-spectrum chemical pesticides if these natural enemies are present in the field.
3. Entomopathogenic fungi can be used to manage *N. viridula*. However, they are mostly effective against the nymphal stages because *M. anisopliae* takes approximately 14 days from treatment to kill adult *N. viridula* (Sosa-Gomez and Moscardi 1998)—a length of infestation that most vegetable legume crops cannot tolerate (Knight and Gurr 2007).
4. Do not spray broad-spectrum chemical pesticides. If necessary, especially under exceedingly high populations of *N. viridula*, spray a systemic pesticide after consulting with local extension staff.

Legume pod borer
Maruca vitrata (F.)
(Lepidoptera: Crambidae)

M. vitrata (syn. *M. testulalis*) is considered the most serious pest of food legumes in tropical Asia, sub-Saharan Africa, South America, North America, Australia and the Pacific (Sharma 1998). *M. vitrata* most likely can feed on at least 45 different host plant species, including two non-leguminous hosts (*Sesamum* sp. and *Hibiscus* sp.) in tropical Asia and sub-Saharan Africa. It is a major pest on at least nine cultivated legume species (*Vigna unguiculata* subsp. *sesquipedalis, V. radiata, V. mungo, Cajanus cajan, Lablab purpureus, Phaseolus angularis, P. vulgaris, Sesbania cannabina* and *S. grandiflora*) year-round. There are relatively few cultivated legumes that serve as the host plant for *M. vitrata* in sub-Saharan Africa, with cowpea (*V. unguiculata*) the predominant host. The majority of *M. vitrata* populations in Africa occur on perennial leguminous shrub or tree hosts, particularly during the main dry season (Tamo *et al*. 2002).

Biology

Egg: The females lay eggs singly or in smaller groups of 2-16 on the floral buds, flowers and pods. Occasionally they are also laid on the leaves, leaf axils, terminal shoots and stem. Eggs are oval in shape and pale yellow in color (Plate 28). The egg period is about 2 to 4 days.

Larva: The larva is whitish to pale brown in color, with irregular but prominent brownish black spots on the dorsal side (Plate 29). The head capsule is light to dark brown. The larva has five instars and the larval period varies from 2 to 3 weeks depending on the temperature.

Pupa: Pupation occurs inside the silken cocoon (Plate 30), either in the soil or under plant debris. Sometimes pupation also takes place within the feeding web in the host plants. The pupal stage lasts for 5 to 10 days.

Adult: The adult moths of *M. vitrata* have light brown forewings with white patches, and white hind wings with an irregular brown border (Plate 31). Wings are 20-25 mm long. It often rests with the wings outspread (Plate 32). Adults live from 1 to 3 weeks.

Plate 28: *Maruca vitrata* – eggs

Plate 29: *Maruca vitrata* – larva

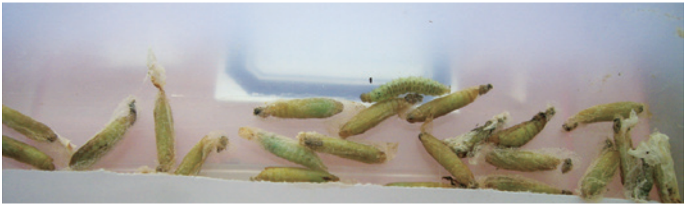


Plate 30: *Maruca vitrata* – pupa

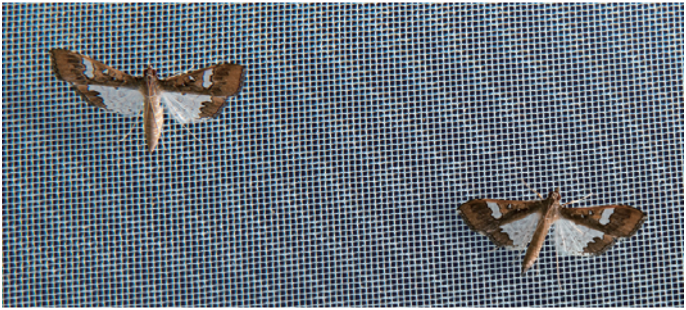


Plate 31: *Maruca vitrata* – adult

Plate 32: *Maruca vitrata* – resting adult

Damage symptoms

Infestation starts in the terminal shoots but later spreads to the reproductive structures (Jackai 1981). The larvae move from one flower to the other, and each may consume about four to six flowers before completing the larval stage. Infestation is highest on flowers (Plate 33), followed by floral buds, pods (Plate 34), and leaves (Karel 1985; Sharma 1998). The mature larvae, especially from the third instar, are capable of damaging pods, and occasionally the peduncle and stems (Taylor 1967). First instar larvae prefer to feed on flowers rather than pods or leaves. The larvae feed on floral buds, flowers, and pods by webbing (Plate 35). Often the damaged pods and inflorescence show frass (Plate 36).

Plate 33: *Maruca vitrata* – damaged flowers

Plate 34: *Maruca vitrata* – damaged pod

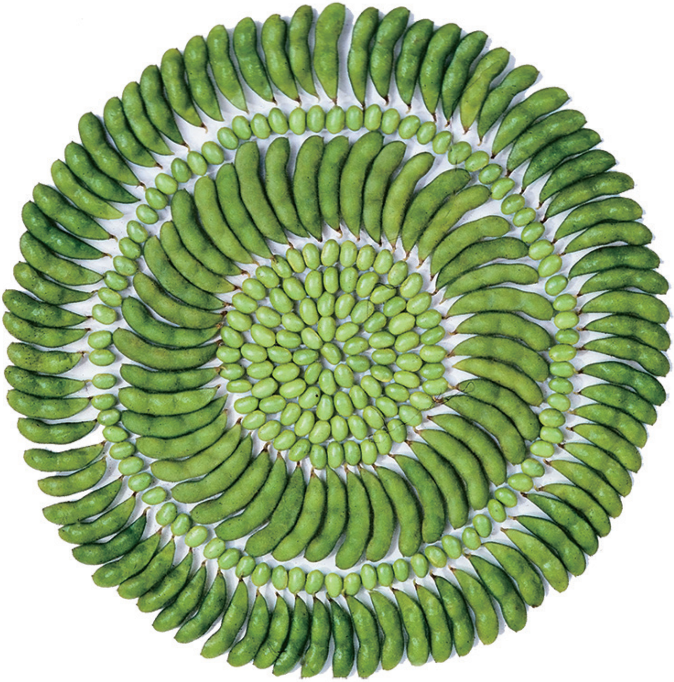
Plate 35: *Maruca vitrata* – damage by webbing

Plate 36: *Maruca vitrata* – damaged pod with frass

Management

1. Early sown crops may escape from *M. vitrata* damage, because the pod borer population tends to increase over the season.
2. Mixed cropping and intercropping can reduce the incidence of *M. vitrata*. For instance, intercropping of common bean with maize significantly minimizes pod borer damage on beans.
3. Grow Sunn hemp (*Crotalaria juncea*) as a trap crop against *M. vitrata*. The plant is highly attractive to the egg laying female moths, but highly unsuitable for the developing larvae of *M. vitrata*, and thus can be used as a 'dead-end' trap crop (Jackai and Singh 1983).
4. Sex pheromone lures of *M. vitrata* are commercially available and can be used for monitoring.

5. *Maruca vitrata* multiple nucleopolyhedrovirus (MaviMNPV) recently has been developed as a biopesticide in Taiwan and Benin (Tamo *et al*. 2012), and can be used to replace chemical pesticides. SlNPV is effective either alone or in combination with neem. In addition, B*acillus thuringiensis* formulations (AVRDC 1996 and 1997; Srinivasan 2008; Yule and Srinivasan 2013) and entomopathogenic fungi such as *B. bassiana* and *M. anisopliae* isolates and/or formulations (Ekesi *et al*. 2002; Sunitha *et al*. 2008; Sreekanth and Seshamahalakshmi 2012) can be used to manage *M. vitrata*.
6. Several parasitoid species have been reported for *M. vitrata* in tropical Asia and Africa (Ulrichs *et al*. 2001; Huang *et al*. 2003; Arodokoun et al. 2006; Muniappan *et al*. 2012). However, most are generalist parasitoids. Recently, AVRDC – The World Vegetable Center identified three relatively specific parasitoids *viz*., an egg-larval parasitoid, *Phanerotoma syleptae* Zettel, and two larval parasitoids, *Therophilus javanus* Bhat & Gupta and *T. marucae* van Achterberg & Long) of *M. vitrata* (Srinivasan *et al*. 2013), and developed pilot production methods (Yule and Srinivasan 2012). These parasitoids are commonly present in Southeast Asia, and they could be conserved and/or released in vegetable legume fields at regular intervals to check the build-up of *M. vitrata*.
7. Chemical pesticides can be applied as needed. Chemical pesticides may highly be effective against early larval stages, before the larvae entering into the reproductive parts of the plants. Avoid using the same pesticide group or compounds having the same mode of action, since *M. vitrata* is able to develop resistance quickly. Consult the local extension agency for appropriate recommendations.



Lima bean pod borer

Etiella zinckenella Treitschke

(Lepidoptera: Pyralidae)

E. zinckenella widely occurs in Asia, sub-Saharan Africa, South America, North America, Australia, Europe and the Caribbean (Chhabra *et al*. 1993). Although it has been reported on several legume crops, it causes significant yield losses in lentil, peas and soybean.

Biology

Egg: The females lay eggs singly or in smaller groups of 2-12 on immature pods and around the calyx. Eggs are shiny white. The egg period is about 4 to 5 days, although it could be as high as three weeks under low temperature.

Larva: The upper surface (dorsal side) of the larva is reddish-pink, whereas the sides and the lower surface of the body are pale green in color (Plate 37). The larval period varies from 3 to 6 weeks depending on the temperature. In parts of Russia and neighboring countries, it overwinters as larva. Toward pupation, the larva moves down to the soil surface for pupation either in the soil or under plant debris.

Pupa: Pupa is light green when newly formed, and later it turns to light brown. The pupal stage lasts for 1 to 3 weeks.

Adult: The adult is a grayish brown snout moth (Plate 38). The forewings have a distinct pale-white band along the costal margin. Hind wings are partially transparent with a dark marginal line (Chhabra *et al*. 1993). Wings are about 20 mm long. Adults live 2 to 3 weeks.

Plate 37: *Etiella zinckenella* – larva

Plate 38: *Etiella zinckenella* – adult

Damage symptoms

Infestation of *E. zinckenella* usually starts late in the season. The larvae feed on floral buds, flowers, and pods (Plate 39) by making rough and irregular incisions. The pods may have several entry holes. They feed on the seeds inside the pods (Plate 40). Often the damaged pods and inflorescence show light colored frass and loosely spun webs.

Plate 39: *Etiella zinckenella* – damaged pods

Plate 40: *Etiella zinckenella* – damaged seeds

Management

1. Choose tolerant or resistant cultivars available in the region. For instance, the soybean accession PI 227687 is consistently resistant to *E. zinckenella* (Talekar and Lin 1994). Consult the local extension agency for the availability of tolerant or resistant varieties.
2. Sex pheromone lures of *E. zinckenella* are commercially available, and can be used for monitoring.
3. Several parasitoid species have been reported for *E. zinckenella* in tropical Asia, Europe and North America. For instance, *Apanteles hanoii* Tobias & Long, *A. taragamae* Viereck, *Bracon* sp., *Trathala flavoorbitalis* (Cameron) and *Tropobracon luteus* Cameron have been recorded from *E. zinckenella* in Vietnam (Long and Hoa 2012). *Trichogrammatoidea bactrae* Nagaraja and *Trichogramma ostriniae* Pang and Chen were found to parasitize 80% eggs of *E. zinckenella* (AVRDC 1992). *Iconella etiellae* Viereck has been reported on *E. zinckenella* from western and central USA (Fernández-Triana *et al*. 2013). These parasitoids could be conserved and/or released in classical biological control programs to check the build-up of *E. zinckenella* in vegetable legume fields. Avoid using broad-spectrum chemical pesticides if these natural enemies are present in the field.
4. Biopesticides such as *B. thuringiensis* and neem are highly effective against *E. zinckenella* (Byrappa *et al*. 2012). Use biopesticides if they are available and recommended in the region.
5. Do not spray broad-spectrum chemical pesticides. If necessary, spray a systemic pesticide after consulting with local extension staff.

Blue butterfly

Lampides boeticus (L.), *Euchrysops cnejus* (F.)

(Lepidoptera: Lycaenidae)

Blue butterflies occasionally cause serious yield losses in food legumes in Asia, sub-Saharan Africa, Europe, Australia and the Pacific. They mainly feed on legumes.

Biology

Egg: The spherical shaped eggs are laid singly on floral buds, flowers and immature pods. Sometimes they are also laid on growing shoots and leaves. Eggs are pale blue or greenish white in color. The egg period is about 4 to 7 days.

Larva: The larva is relatively sedentary and it is yellowish green in color. The entire body of the larva has small and sparse setae. In general, the larva looks like a slug (Plate 41). The larval period varies from 2 to 4 weeks depending on the temperature.

Pupa: Pupation occurs on the leaves, twigs and pods, and to some extent in the soil or under plant debris. Pupa is reddish brown. The pupal stage lasts for a week.

Adult: The adult is a medium-sized butterfly. The wings are metallic blue to dusky blue in color. The tail of hind wings is black and tipped with white (Chhabra *et al*. 1993). Wings are about 3 cm long.

Damage symptoms

The larva bores into the floral buds (Plate 42), flowers and green pods soon after emergence from eggs, and feeds on the inner contents. Damage on the pods is characterized by round holes.

Plate 41: Blue butterfly – larva

Plate 42: Blue butterfly – damage

Management

1. Blue butterfly larvae occur infrequently in vegetable legumes. In addition, they are attacked by several parasitoids such as *Trichogramma chilotraeae* Nagaraja & Nagarkatti, *T. bactrae* and *Cotesia specularis* Szepligeti. Hence specific control measures do not necessarily target blue butterflies.
2. If necessary, spray the most effective biopesticides based on *Paecilomyces lilacinus*, *Vetricillium lecani* and neem (Arivudainambi and Vijay Chandar 2009). These are superior to *B. thuringiensis* and other entomopathogenic fungi.

Gram pod borer

Helicoverpa armigera Hübner

(Lepidoptera: Noctuidae)

The gram pod borer is a polyphagous and highly mobile insect and it is a pest of economic importance on many agricultural and horticultural crops. It is a major pest on a number of crops, including cotton, tobacco, corn, sorghum, sunflower, soybean, lucerne and pepper (Torres-Villa *et al*. 1996). It has been recorded on 180 cultivated and wild plant species in at least 45 families (Venette *et al*. 2003). Occasionally it causes significant yield losses in mungbean, vegetable soybean, chickpea and pigeon pea.

Biology

<u>Egg</u>: The adults lay eggs singly and scattered, usually on or near the leaflets, floral buds or young pods. The eggs are spherical, about 0.5 mm in diameter, creamy white when laid, but later turn to brown and black just before hatching. The egg period is about 4 to 5 days depending on the temperature.

<u>Larva</u>: Upon hatching, the neonate larvae are creamy white with dark brown or black colored heads and prominent spines on the body. The grown-up larvae vary in color from pale green to brown or even black with lateral stripes on the body (Plate 43). Mature larvae can grow to about 4 cm in length. The larval period is about 15 to 25 days. The larva passes through six instars.

<u>Pupa</u>: Pupation takes place in soil, but sometimes also on plants. Pupae are dark brown (Plate 44). The pupal period varies from 6 to 33 days depending on the temperature. On average, it is about 10 days to two weeks.
<u>Adult</u>: Adults are stout-bodied moths with a wingspan of about 3.5–4 cm (Plate 45). Adult males are usually pale

yellow in color with olive green or grey; adult females are reddish brown. The male forewings are pale yellow and olive green with light brown obscure transverse lines; female forewings are reddish brown with distinct brownish black transverse lines. The hind wings are white with a brown border.

Plate 43: *Helicoverpa armigera* – larva

Plate 44: *Helicoverpa armigera* – pupa

Plate 45: *Helicoverpa armigera* - adult

Damage symptoms

The neonate larvae feed on the surfaces of leaves or floral buds. However, the grown-up larvae prefer to feed on the contents of reproductive parts such as floral buds, flowers and young fruits. The larvae make the holes on these reproductive parts and feed inside by thrusting their head inside (Plate 46); hence the holes are circular and often surrounded by fecal pellets. Later, the larva feeds on most of the inner contents of the pod and hollows the pod out. Severely damaged pods rot and fall; partially damaged pods may become deformed.

Management

1. Avoid growing legumes in the vicinity of other alternate host plants, because the *H. armigera* adults can easily migrate to the newly planted legume crop. It may be too difficult to avoid this situation in countries where the land is highly fragmented.

Plate 46: *Helicoverpa armigera* damage on pods

Erecting suitable physical barriers such as nylon nets or planting barrier crops that are non-host plants around the plots can reduce *H. armigera* damage on vegetable legumes. However, these measures cannot prevent the complete entry of the insects, as they are strong flyers.

2. Crop rotation should strictly be followed. If the growers plant vegetable legume (*e.g.*, mungbean) after mungbean or other alternate host plants such as tomato, chickpea, corn, cotton, etc, the damage will be higher from the emerging insects that already pupated in the soil during the previous crop cycle. This is more serious in locations where *H. armigera* diapause occurs during winter. Rotate the legume crop with a non-host cereal crop, cucurbit or cruciferous vegetable.

3. *H. armigera* sex pheromone traps can be used to monitor, mass-trap or disrupt the mating activities of male moths.
a. *Monitoring*: Sex pheromone traps baited with *H. armigera* pheromone lures can trap adult male moths to predict the population build-up in the field.
b. *Mass-trapping*: Sex pheromone traps baited with *H. armigera* pheromone lures can be used for trapping as many males as possible to reduce chances of females mating and producing viable eggs in the field. However, this has limited effect for polyphagous insects like *H. armigera*, since its population is always higher due to the availability of multiple host plants in crop production systems in the tropics.
c. *Mating disruption*: High concentration of full blends or, at times, only one component of the multi-component pheromone is placed in the field to permeate the area with the synthetic chemical. The high concentration of pheromone in the air overwhelms the male, making it impossible to locate a receptive female. Failure to mate results in failure to produce eggs or the production of only nonviable eggs, which reduces the build-up of insect populations. Placing a high concentration of sex pheromone in a slow-release formulation on a 5- and 10-m grid in the field will result in a drastic reduction in male moths being attracted to virgin females, which adversely affects mating in *H. armigera* (AVRDC 1988).
4. Planting of African marigold (*Tagetes erecta* L.) as a trap crop reduces the incidence of *H. armigera*. *H. armigera* adults preferred marigold at flowering stage for oviposition. It is important to synchronize sowing/

transplanting of both crops so that their flowering coincides to attract *H. armigera* female adults.

5. The egg-parasitoids (*e.g.*, *Trichogramma pretiosum* Riley) and larval parasitoids (*e.g.*, *Campoletis chlorideae* Uchida) can be conserved and/or released in vegetable legume fields at regular intervals to check the build-up of *H. armigera*. If these parasitoids are present in the field, avoid using broad-spectrum chemical pesticides, which would be lethal to these natural enemies.
6. Commercially available biopesticides based on *B. thuringiensis*, *Helicoverpa armigera* nucleopolyhedrovirus (HaNPV) and neem can also be used against *H. armigera*. However, proper rotation should be followed while applying *B. thuringiensis* formulations to avoid development of resistance. For instance, *B. thuringiensis* subsp. *kurstaki*-based formulations could be rotated with *B. thuringiensis* subsp. *aizawai*-based formulations.
7. Chemical pesticides are widely used against this noxious insect in several parts of the world. Chemical pesticides are very effective against early larval stages, before the larvae enter into floral buds or pods. Pesticide spraying should be scheduled soon after noticing the eggs or early larval stages. As it would be laborious to monitor these stages, it could be coordinated with the sex-pheromone trap catches. However, proper pesticide rotation should be followed when using chemical pesticides. The effectiveness of these chemicals in the region and the registration status for the target legume crop should be checked before using.

Spider mite
Tetranychus spp.
(Acari: Tetranychidae)

Spider mites emerged as a serious pest of vegetable crops including vegetable legumes, eggplant, tomato, cucumber, and other field crops in South and 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
Spider mites 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 2 to 4 days. Upon hatching, spider mites will pass through a larval stage and two nymphal stages (protonymph and deutonymph) before becoming adults. The lifecycle is completed in 1 to 2 weeks. There are several overlapping generations in a year. The adult lives up to 3 to 4 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. In severe infestations, leaves will completely desiccate and drop off. The mites also produce webbing on the leaf (Plate 47) and pod surfaces (Plate 48) in severe conditions. Under high population densities, the mites move to the tip of the leaf or top of the plant and congregate using strands of silk to form a ball-like mass (Plate 49), which will be blown by winds to new leaves or plants, in a process known as “ballooning.”

Plate 47: Webbing of leaves by spider mites

Plate 48: Webbing of pods by spider mites

Plate 49: Congregation of spider mites in the leaf tip

Management

1. 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.
2. 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.

3. Green lacewings (*Mallada basalis* Walker and *Chrysoperla carnea* Stephens) also are effective generalist predators of spider mites. A third instar grub of *C. carnea* can consume 25–30 spider mite adults per day; however, it needs supplemental food for long-term survival (Hazarika *et al*. 2001).
4. 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.

Bruchids

***Callosobruchus chinensis* L., *C. maculatus* Fab.**

(Coleoptera: Bruchidae)

Bruchids have been reported from South and Southeast Asia, Africa, China, Taiwan and North America. They mainly attack grain legumes in storage, but also have been reported to attack corn, sorghum and cotton seeds (Chhabra *et al*. 1993).

Biology

The eggs are glued on to the surface of the grain in storage (Plate 50), or on green pods if the infestation starts in the field. Although the eggs are laid singly, several eggs may be seen on a grain or pod. The eggs are elongate, oval and scale-like. When freshly laid, the eggs are translucent. However, they turn to pale yellow before hatching. The egg period is about one week, but may take more than two weeks at low temperature.

The young grub feeds inside the grains, and completes its development. The grub period is 2 to 5 weeks depending on the temperature. However, it hibernates during the winter, and hence it completes its grub development in 4 to 5 months (Chhabra *et al*. 1993). The mature grub is about 0.5 cm long and white in color with a brown head.

The pupa is oval in shape and white in color. Pupal stage lasts for 1 to 4 weeks depending on the temperature.

The adult beetle is 3-4 mm in length. *C. chinensis* is reddish brown in color (Plate 51), whereas *C. maculatus* has grey wings with four black spots (Plate 52) (Chhabra *et al*. 1993).

Plate 50: Bruchid eggs

Plate 51: *Callosobruchus chinensis* – adult

Plate 52: *Callosobruchus maculatus* - adult

Damage symptoms

The grub remains curved inside the grains and feeds, emptying out the seeds (Plate 53). When multiple generations occur repeatedly in the same seed lot, almost the entire grain is damaged, leaving a foul-flavored flour. Usually bruchid damage starts right from the field. Adults emerging from the initial infestation lead to a secondary infestation in storage, which is much more damaging (Talekar 1990). An initial infestation of 10% could lead to 100% grain loss in storage within 3 to 5 months under ordinary storage conditions (Chhabra *et al*. 1993).

Plate 53: Bruchid damage

Management

1. Choose tolerant or resistant cultivars available in the region. For instance, TVu 2027 is a well-known bruchid resistant cowpea variety from IITA (Singh 1977). Two black gram accessions, VM2011 and VM2164, are highly resistant to *C. chinensis*, whereas two mungbean accessions (V2802, V2709) recently have been confirmed to possess complete resistance for *C. chinensis* and *C. maculatus* (Somta *et al*. 2007). Consult the local extension agency for the availability of tolerant or resistant varieties.
2. Storage of legume grains or seeds in air-tight containers is an effective way to eliminate bruchids, as they are unable to survive without air. Triple-bagging legume grains for storage can substantially reduce bruchid infestation (Kitch and Ntoukam 1991a). This method recently has been promoted as Purdue Improved Cowpea Storage (PICS) technology (Baributsa *et al*. 2013). The PICS bag is a triple-layer plastic bag that serves as an air-tight (hermetic) way to store cowpea grain. Two high-density polyethylene (HDPE) inner bags fit inside an outer sack composed of woven polypropylene (PP). The inner HDPE liners have a wall thickness of 80 microns. The liners greatly hinder the movement of oxygen across the wall of the bag. The tough outer woven bag enables the bag to be easily handled.
3. Treating the legume grains with clays, sand, kaolin, and ash has been proven effective in controlling bruchid infestation in storage (Alice and Srikanth

2013). For instance, using attapulgite dust at the rate of 10-50 grams per kilogram of black gram seeds as a protectant reduced the *C. maculatus* infestation up to 135 days, without affecting seed viability (Pandey and Verma 1977). Treating cowpeas with activated kaolin at the rate of 10 grams per kilogram completely reduced the damage of *C. chinensis* for about 225 days (Swamiappan *et al*. 1976). When cowpea seeds are mixed with an equivalent volume of ash, they are protected from bruchids (Kitch and Ntoukam 1991b).

4. Vegetable oils (e.g. olive oil or mustard oil at the rate of 15 ml/kg of seed) can also be used to treat legume grains and seeds to protect from bruchid infestation. However, some vegetable oils may reduce seed viability.
5. Novel gadgets such as traps (e.g. pitfall trap and probe trap) can be used to monitor as well as mass-trap bruchids in storage. A prototype of a gadget that can successfully crush the eggs of bruchids has been introduced. The gadget has an outer container and an inner perforated container with a rotating rod fixed with plastic brushes on all sides. The legume seeds with eggs are stored in the perforated container and the rod must be rotated one full circumference clockwise and anti-clockwise for 10 minutes three times a day. Due to the action of the rotating brush, the eggs are crushed and damage is prevented. The treatment does not affect seed germination (Mohan 2006).

Integrated pest management approaches for insect and mite pests of vegetable legumes

Cultural control

1. Avoid vegetable legume monocultures and follow crop rotations.
2. Avoid growing legumes in the vicinity of other alternate host plants, because pests can easily migrate to the newly planted legume crop. However, it may be too difficult to avoid this situation in countries where the land is highly fragmented. Erecting suitable physical barriers such as nylon nets or planting barrier crops that are non-host plants around the plots can reduce pest damage on vegetable legumes. However, these measures cannot prevent the complete entry of insects as they are strong flyers.
3. Keep weeds under control in vegetable legume seedling production areas as well as in main fields to reduce the availability of alternate host plants for some of the major insect pests.
4. Grow trap crops, and focus pesticide spraying on the trap crop to manage bean flies, *S. litura, Riptortus* bugs, *N. viridula, M. vitrata* and *H. armigera*. Plant tall border crops like maize, sorghum, or pearl millet to reduce the infestation of whiteflies.
5. Early sowing or planting may reduce the damage of bean flies and *M. vitrata*.
6. Triple bagging, or treating legume grain or seed with clays, sand, kaolin, ash and vegetable oils may reduce the damage by bruchids in storage.

Host plant resistance

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

Mechanical control

8. Grow seedlings for crops such as yard-long bean and common bean in insect-proof (50–64 mesh) net houses, net tunnels, greenhouses, or plastic houses.
9. Novel gadgets such as traps (e.g. pitfall trap and probe trap) can be used to mass-trap bruchid beetles, and to crush bruchid eggs in storage.

Plate 54: Yellow sticky paper traps to monitor whitefly and leafhoppers

Plate 55: Blue sticky paper traps to monitor thrips

Behavioral control

10. To monitor insect populations, use yellow sticky traps (Plate 54) to attract whitefly and leafhoppers and blue sticky traps (Plate 55) to attract thrips.

11. Use reflective and yellow plastic or straw mulches to reduce the incidence of whiteflies and thrips on vegetable legume crops.

Biological control

12. Apply neem formulations and other systemic chemical pesticides, if recommended in the region, as soil drenches or through foliar application to control whitefly and aphids in vegetable legume seedling production.
13. Use neem, entomopathogenic fungi, *B. thuringiensis* based biopesticides, and botanical extracts, which will not interfere with the activities of natural enemies (Plates 56-62) in vegetable legume production systems.

Plate 56: Predator (Syrphid fly) – adult

Plate 57: Predatory ladybird beetle – larva

Plate 58: Predatory ladybird beetle – pupa

Plate 59: Predatory ladybird beetle – adult

Plate 60: Predatory ladybird beetle – adult

Plate 61: Predatory ladybird beetle – adult

Plate 62: Parasitized aphid

14. Install sex pheromone lures (Plate 63) for insects such as *S. litura, S. exigua, M. vitrata, E. zinckenella* and *H. armigera*, and aggregation pheromone lures for *Riptortus* bugs in traps. 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.

Plate 63: Sex pheromone traps to mass-trap pod borer moths

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. Do not use the same compound or pesticide group(s) continuously to reduce the development of pesticide resistance in insects. Applying chemical pesticides via seed treatment and soil drenching will avoid direct contact of pesticides with natural enemies.

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 can kill wide range of species in an ecosystem
Canopy	:	Uppermost foliage cover in a plant or tree
Chlorophyll	:	Green pigment that 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
Desiccate	:	Become dried
Deutonymph	:	The second nymphal stage in mites. Mostly, the deutonymph molts in to adult stage
Exuvia (also exuvium; plural: exuviae)	:	Cast skin or shed skin after molting
Frass	:	Mixture of chewed plant debris, feces and other excretions
Grub	:	Larval stage in certain insect orders including Coleoptera
Honeydew	:	Liquid feces 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 an instar.
Macrocyclic lactones	:	Products or their chemical derivatives of soil borne actinobacteria belonging to the genus, Streptomyces

Maggot	:	Larval stage in diptera (flies)
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
Nymph	:	Larval stage in certain insect orders including Hemiptera. Nymphs will directly develop into adults without undergoing pupal stage.
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 the embryo occurs without fertilization by a male insect
Pesticide resistance	:	Inheritable tolerance to pesticides among pest populations of a species
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)
Setae (singular: seta)	:	Hair-like or bristle structures
Skeletonization	:	Process of destroying the tissues and leaving the basic structure or shape (of the leaves)
Sooty mold	:	Black powdery coat on the leaf surfaces due to the growth of saprophytic fungi on the excretions (honeydew) of certain homopteran insects
Systemic pesticide	:	Pesticide that translocates throughout the plant system after application
Maggot	:	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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